MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XX., PART 2.

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PREFACE.

THE present is, in all probability, the last description of geological surveying in India that I shall ever write. After taking part in the work of the Geological Survey for more than twenty-seven years, I am reluctantly compelled to forego the hope of aiding any longer in its labours. So much exploration and study are necessary before the many difficult problems presented by Indian geology can be solved, even to the imperfect extent that similar problems have been solved in countries where observers are more numerous, and physical difficulties less, that it is some satisfaction to reflect upon the progress that has been made, and to contrast our present knowledge of Indian geology with that which was available a quarter of a century ago. But although to any geologist now entering upon the study of Indian formations for the first time the amount of accumulated information may appear imposing, to one who has assisted in the research, and is now quitting the field, the links that are wanting to complete the chain appear more numerous than those that have been forged, and the gaps are more conspicuous than the finished work.

The present memoir is an account of an attempt to forge one of these missing links, and to apply the knowledge of tertiary rocks gained in one part of the country, Sind, to

throw light upon the structure of a more difficult region, the Punjab.

The study of the Indian tertiaries was unfortunately commenced at the wrong end. This was due neither to error nor ignorance, but was partly caused by the arrangements for geological work depending largely upon the progress of topographical surveying, and partly by the necessity of exploring particular tracts of country in order to ascertain the distribution of valuable minerals. For these reasons, the confused and imperfect series of tertiary rocks exposed in Burmah, the Assam Hills, the North-West Himalayas, and the Punjab, came under the notice of the Survey before the superb and richly fossiliferous sections of the Sind hills had been studied. Now that, at length, some knowledge of the Sind tertiary formations has been attained, it is essential that the knowledge procured should be applied to the classification of the rocks in the other tertiary regions of India.

The process is two-fold. The palæontological collections from Sind require careful study and description, and the stratigraphical divisions require tracing in the field in connexion with those in neighbouring parts of the country. In the former branch of the subject a little has been done already. Professor P. Martin Duncan has very kindly described and figured the corals of the Sind rocks, and is now engaged, with the co-operation of Mr. Percy Sladen, in describing the still more important collection of *Echinoidea* from the same beds. To these two gentlemen Indian geologists are deeply indebted. But until the fossil mollusca of Sind have been determined and figured, the palæontological materials for the study of the Indian tertiaries will continue

to be not only imperfect but misleading. The only important contribution to the subject, the well known work of Messrs. D'Archiac and Haime on Indian nummulitic fossils, not only includes forms from lower and upper eocene, oligocene, and miocene beds, all attributed to the eocene, but, owing to the very imperfect state of preservation in which many of the specimens were, neither the figures nor descriptions of a considerable proportion of the species are satisfactory. I am indebted to Professor Martin Duncan for especially calling my attention to this circumstance. There is unfortunately no question but that many of the identifications of Indian tertiary fossils made by the aid of Messrs. D'Archiac and Haime's work are erroneous, and amongst the names that will require revision are some of those contained in the lists drawn up by Mr. Fedden and myself, and published as an appendix to the description of the geology of Western Sind in the seventeenth volume of these memoirs. Most of the lists of tertiary invertebrata quoted in the Manual of the Geology of India suffer from the same disadvantage.

The season's work, of which the present memoir gives an account, was devoted mainly to the other branch of the process, to the endeavour to trace a connexion between the tertiary deposits of Sind and those of the Punjab by following the rocks themselves to the northward. The results, as will be seen, were fairly successful, and in the case of the Lower Manchhar or Siwalik beds some interesting additions were made to the fauna previously known. At the same time a rough geological sketch was made of a considerable tract of country, not always very easy of access, along the

frontier of British India. This tract had hitherto been represented by a blank upon the geological map.

In the course of the season's work it was necessary to traverse a portion of the ground in the Bolán Pass and near Quetta, recently described by Mr. Griesbach in the eighteenth volume of these memoirs. On some geological questions, I have come to conclusions differing from his, and I have, in the following pages, explained the differences between us and my reasons for not concurring in Mr. Griesbach's opinions. Some surprise has been expressed in Europe at the circumstance that members of the Indian Geological Survey publish criticisms of each other's work; it is therefore necessary to explain that the opportunities for doing so are comparatively rare; that it is very unusual for one surveyor to examine the work of another immediately after an account of the latter has appeared, and also that, owing to the size of the country, and to many parts of it being difficult of access, anything like efficient supervision of the work is impracticable, whilst there are no independent scientific observers, as in Europe, to call attention to mistakes and to enforce the necessity of caution in expressing opinions. In fact the want of intelligent external criticism is one of the most serious disadvantages under which the Indian Survey labours, and the only method of compensating for this drawback, and of obtaining the scientific advantages that always result from a discussion of different views, is for Indian Surveyors to criticise each other's work and to notice all points on which difference of opinion exists. Even if no other advantage be gained, future observers, by being placed in possession of both sides of the question, will

have an opportunity of ascertaining by further research which opinion is better founded.

It is scarcely necessary to say that geological surveying on the frontier of India and beyond it, especially around the Punjab, is only practicable with much more assistance from the Civil and Military authorities than is requisite in more settled parts of the country. I was greatly indebted, not only for official assistance, but for much personal kindness, to the officers of the Punjab Government and of the Baluchistan Agency, and especially to Sir R. Egerton, Lieutenant-Governor of the Punjab, Colonel Ommaney, the Commissioner of the Derajat, and Mr. Fryer, Deputy Commissioner of Dera Ghazi Khan. I am under at least equal obligations to my old friend Sir O. B. St. John and to Colonel Waterfield, who occupied in succession the post of Political Agent to the Governor General at Quetta, and to Mr. Bruce, Assistant Political Agent at Jacobabad. It would make too long a list to mention all by name to whom I am indebted, but I must express my acknowledgments to General Edwardes of Quetta, Colonel Chambers, 24th Bombay Native Infantry, who commanded at Kach, and, above all, Colonel Lance, 2nd Punjab Cavalry, of Dera Ghazi Khan.

I am also indebted to my friend and former colleague Mr. A. B. Wynne for preparing the drawings used for the frontispiece and some of the sections, and to Dr. H. Woodward of the British Museum for assistance in the illustrations of Siwalik mollusca.

LONDON; W. T. BLANFORD.
October 1883.

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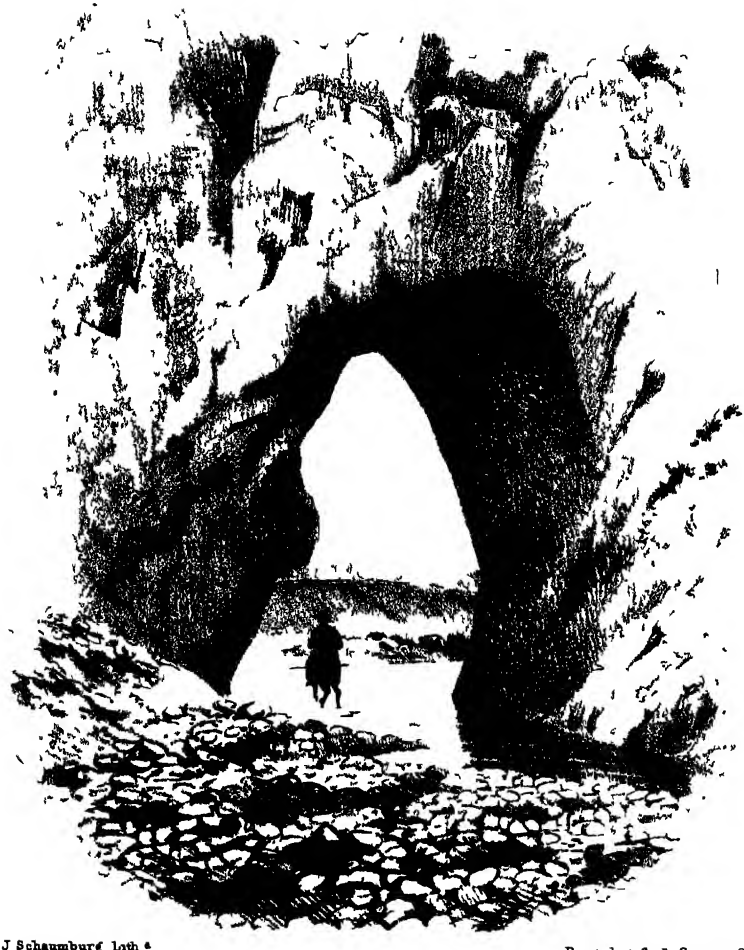

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NATURAL ARCH THROUGH A RIDGE OF SIWALIK CONGLOMERATE NEAR SANGGILA BUGTI HILLS

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

GEOLOGICAL NOTES ON THE HILLS IN THE NEIGHBOURHOOD OF THE SIND AND PUNJAB FRONTIER BETWEEN QUETTA AND DERA GHAZI KHAN, *by* W. T. BLANFORD, F.R.S., &c., *Deputy Superintendent, Geological Survey.*

PART I.—GENERAL.

CHAPTER I.

INTRODUCTION.—PREVIOUS OBSERVERS.

Plan of season's work.

The principal object of the field work done by me in the season 1881-82 was to trace northward the well marked series of tertiary rocks, of which the age has been determined by the occurrence of marine fossils at several different horizons in Sind, and to ascertain how far the classification established in that province could be applied to the tertiary beds of the Punjab. As is well known, in consequence of the absence of marine fossils, or of any well marked subdivisions, it has hitherto been found impracticable, in the last named area, to determine the age of the beds above the eocene,

and their relations to corresponding strata in other countries, with sufficient exactitude.

The route I followed was the following:—

Starting from Sibi, the present terminus of the railway, I marched by the Bolán route to Quetta, and after a few days spent at that place I returned by the Harnai road to Sibi again. I thence proceeded to Jacobabad, skirting the western border of the Bugti hills, and again, leaving Jacobabad, I marched *viâ* Bugti Dera,[1] in the heart of the Bugti country, Siah Tank, the Sham plain and the Cháchar[2] Pass to Harrand in the Southern Deraját, and near the south-eastern extremity of the Punjab. From Harrand I proceeded to examine the Sulemán range, and I had marched northward along its eastern watershed as far as Mangrotha, 50 miles north of Dera Gházi Khán, when I was compelled by illness to leave the field, and I was unable to resume work. Had I not been thus interrupted I might have examined the eastern slopes of the Sulemán range for about 30 miles further north, as far as the frontier of Dera Ismail Khán. South of this frontier the tribes inhabiting the hills are friendly Baluchis, but to the northward all the hill tract is occupied by Pathán tribes, and any attempt to enter the country without a very considerable military force would certainly prove a failure. Very little additional information as to the Sulemán range could consequently have been gained, and time would not have sufficed in any case for the examination of the Northern Punjab.

Route followed.

Difficulty of examining northern Sulemán area.

The tract thus traversed is the border of the Baluch and Afghan highlands. To the eastward the plain of the Indus valley is nearly coterminous with the British frontier, the foot of the hills being, throughout the southern Deraját (or districts of Dera Ismail Khán and Dera Gházi Khán), the limit of British territory. To the westward a considerable tract of plain, includ-

Geography of area examined.

[1] Called Sehâf or Bugti Dera on the accompanying map. The first name properly applies to the surrounding district, not to the fort and small town.

[2] Cachar on map.

ing all the Kachhi or flat country around Sibi, Bhág, Gandáva, &c., belongs to Baluchistan. The Kachhi may be described as a great gulf-like expanse of level ground running north from Sind between the hill ranges of Baluchistan. With the exception of a small portion of Southern Afghanistan, all the area examined is outside the British frontier.

Tracts left unvisited.

Owing to want of time it was impossible to examine two tracts of country in the neighbourhood of the route, and a knowledge of the geology of these areas is still a desideratum. One is the range of hills along the western side of Kachhi between the northern boundary of Sind and the entrance to the Bolán Pass. The other is the Mari country east and north-east of Sibi. Some sulphur mines occur in the former locality near Bágh, and it is possible that mesozoic rocks are found, for Dr. Bellew[1] states that in the Miloh (Mula) Pass, 20 miles beyond Gandáva on the road to Khozdár, "every pebble and every rock is full of madrepores, *ammonites*, *belemnites*, oysters, and other marine fossils." In the Mari hills there is a reported petroleum locality. The ground between the Bolán and Harnai routes still requires examination, although an attempt is made in the accompanying map to suggest the probable distribution of the different systems of rocks.

Petroleum of Mari hills.

Results of season's work.

How far the objects of the season's work were attained will be shown at some length in the following pages. The principal results, however, may be briefly summarized. It should be remembered that the sequence of tertiary and upper cretaceous strata in Sind,[2] and their age, according to the geological scale adopted in Europe, are the following:—

Sequence of beds in Sind	1. Manchhar or Siwalik	Upper	.	Pliocene.
		Lower	.	Upper Miocene.
	2. Gáj		.	Miocene.

[1] From the Indus to the Tigris, p. 40. The observations were made on a hurried journey, and there is, I think, a possibility that eocene fossils may have been mistaken for ammonites and belemnites, for the author does not profess any special knowledge of palæontology.

[2] Mem. G. S. I., Vol. XVII, Pt. 1, p. 32, and Manual of the Geology of India, p. 447.

3. Nari	Upper	Lower Miocene?
	Lower	Oligocene.
4. Khirthar		Eocene.
5. Ranikot		Lower Eocene.
6. Deccan trap, *Cardita beaumonti* beds[1] and sandstones		Passage beds between cretaceous and tertiary.
7. Limestone with *Hippurit*		Cretaceous.

Of these various systems and groups, the Siwalik or Manchhar continues almost unaltered from Sind into the Western Punjab, both the upper and lower subdivisions being not only well represented, but easily distinguishable from each other, as far north as the Sulemán range was examined. The lower subdivision, however, is wanting near Sibi and Quetta. Of the Gáj group, on the other hand, no trace was detected north of Sind, the beds near Quetta and Sibi that were referred to that group by Mr. Griesbach [2] being, I think, certainly Siwalik, as will be shown subsequently. The oligocene limestone (lower Nari) was seen at one locality in the Bolán Pass, but is wanting throughout the rest of the country; the upper Nari sandstones, however, although not observed in the Bolán, and absent on the Harnai route, and throughout the greater portion of the Bugti hills, re-appear to the eastward, and are found fairly represented throughout the eastern flank of the Sulemán range as far north as the examination was carried. Thus it will be seen that the change in the upper tertiary beds, in passing from the Khirthar range of Sind to the Sulemán of the Punjab, consists in the entire disappearance of the two marine subdivi-

Representation of Sind groups to northward.

[1] These and the underlying sandstones I have hitherto (*l. c.*) classed as cretaceous. The examination of the corals and echinoderms by Professor P. M. Duncan shows, however, that, despite some species with very marked cretaceous affinities, there is, on the whole, a preponderance of tertiary forms. The olive shales too, which form a considerable proportion of the subdivision, prove, further north, to be characteristic eocene beds, and there seems great reason to believe that the *Cardita beaumonti* beds, whatever their exact age may be, must be classed for stratigraphical reasons with the eocene rather than with the cretaceous system of Western India.

[2] Mem. G. S. I., Vol. XVIII., Pt. 1, p. 18.

sions, the lower Nari (oligocene) and the Gáj (miocene) of the first named hills.

Of the older tertiary beds the nummulitic group or Khirthar of Sind is everywhere well represented, but the Ranikot has not been detected again, and appears very possibly to be a local stage with a peculiar and rich fauna. The eocene beds of the Sulemán range have at the base a considerable thickness of hard brown sandstone.

Previous observers.

The geologists who have described portions of the area noticed are not numerous, and with but very few exceptions their attention was confined to the Bolán Pass and its neighbourhood. Only two papers of any importance—one by Captain Vicary, on the Bugti hills, the other by Mr. Ball, on a section across the Sulemán range—refer to other parts of the area traversed. It will be most convenient to notice first the geological descriptions of the Bolán Pass and its vicinity, including Quetta, by themselves, and then to pass in brief review the papers referring to the geology of other parts of the area.

Papers on Bolán Pass and neighbourhood.

Most of the travellers who visited Afghanistan before the first Afghan war passed at one time or another through the Bolán Pass, which then, as now, was the principal trade route between Sind and Afghanistan. Descriptions of the pass were given by Conolly, Masson, and others, but no details were mentioned of geological interest.

Griffiths, 1841.

In Dr. Griffiths' "Extracts from reports on subjects connected with Afghanistan," published in 1841,[1] he called attention to the peculiar forms of the valleys and plains of Afghanistan, and cited as examples some of those around Quetta. He especially noticed the slopes of gravel, or "glacis slopes" as he very appropriately called them, along the margins of the plains.

[1] J. A. S. B., Vol. X, p. 803.

He differed from Lord,[1] who attributed the drainage of the valleys around Cabul, supposed to have been originally lakes, to a great rush of water through the Khyber Pass. In Dr. Griffiths' "Private Journals," published in 1847, there are many notes,[2] chiefly botanical, on the observations made by their author in the Bolán Pass, but few, if any, of geological interest.

Griffiths, 1847.

In the Journal of the Royal Geographical Society for 1842[3] is an extract from a letter written by an officer in the Bengal Artillery and giving some notes on the Bolán Pass. These include a few details of the rocks; the coal near Ab-i-gúm (Mach) is especially mentioned, and its high dip graphically represented.

Anon., 1842.

The earliest detailed account of the geology of the Bolán Pass was published in 1846 by Captain T. Hutton, in his "Notes on the geology and mineralogy of Afghanistan."[4] After describing the sulphur mines of Bágh, he gave an account of the low hills on the road between Bágh and Dádar, noticed the presence of foliated gypsum, and referred the beds to the tertiary period, to which, when Hutton wrote, the nummulitics were not supposed to belong. He then described the rocks at the entrance to the Bolán as composed of alternating strata of sandstone, clay, and conglomerate. He recorded the appearance above Condye (Kohandiláni) of nummulitic limestone, and its identity with the rock seen at Sukkur on the Indus, and gave an account of the stony plain of Keirtah (Kirta), which he says is enclosed on the left (west) by strata of sand and clay and on the right (east) by nummulitic limestone. This is not quite the case; nummulitic limestone occurs on both sides, but there are some argillaceous and sandy beds underlying the limestone.

Hutton, 1846.

[1] J. A. S. B., Vol. VII, p. 521. Dr. Lord's paper entitled "Some account of the Koh-i-Daman, the mining district of Ghorband and the pass of Hindu-Kush" is a valuable contribution to the geology of Afghanistan. It has been overlooked by Mr. Griesbach, and is not included in his list of papers on the geology.

[2] Pages 330-341.

[3] Vol. XII, p. 109.

[4] Calcutta Jour. Nat. Hist., Vol. VI, p. 562.

Near Ab-i-gúm, Captain Hutton found masses, not *in situ*, of indurated marly clay containing fresh-water shells, amongst which Mr. Benson recognised *Melania pyramis (M. tuberculata)*, *M. elegans (M. scabra)*, and *Planorbis indicus (P. exustus)*, also *Unio*, *Cyrena* (*i.e.*, *Corbicula*) and *Paludina*. Captain Hutton could not tell precisely whence the fragments came, but thought they were washed down from some of the hills, and he remarked upon the occurrence of similar shells in Siwalik strata. These fossils do not appear to have been noticed by subsequent observers. No mollusca have yet been obtained from the Upper Siwalik beds of Sind or of the Western Punjab, whilst the fossiliferous Lower Siwaliks are not known to occur in the Bolán Pass. Perhaps, the marls with shells were of post-tertiary age.

The rocks of the upper part of the pass were equally well observed, but, misled apparently by the idea that the coal beds between Sir-i-Bolán and Ab-i-gúm must be of carboniferous age, Hutton supposed the cretaceous limestones around Dozán and along the borders of the Dasht-i-bedaolat to be mountain limestone, and the olive shales and coals of Mach to belong to the coal formation; whilst he thought he found specimens of oolite at Ab-i-gúm. The nummulitics were of course classed as cretaceous. On the other hand, he recognised the resemblance of the sandstones and conglomerates at the foot of the pass, and "opposite to the strata of shales near Sir-i-Bolán," to the Siwalik tertiary strata, and if, as I suspect, the conglomerate near Sir-i-Bolán is the same as that about Ab-i-gúm and around the Kirta plain, he was in all probability right in both cases.

The immense accumulations of rounded water-worn stones dispersed over such plains as that of Kirta were noticed. These accumulations could not, Hutton thought, have been formed in lakes, but must have been deposited in "deep waters..... in violent agitation," and he attributed them to a great rush of water [1] due to the elevation of the strata after the tertiary (*i.e.*, Siwalik) beds were deposited.

[1] A series of papers now being published in the Geological Magazine under the title "Traces of a great post-glacial flood" is devoted to an attempt to re-establish the theories held by Hutton's contemporaries.

Passing onwards from Quetta towards Pishin, he noticed the recurrence of tertiary clays and sandstones, and remarked on the presence in them of foliated gypsum, as near Dádar. Hence, quite correctly, he identified the Pishin and Dádar rocks. He also made some very acute observations on the form of the hills, attributing it to weathering (*i.e.*, subaërial action), and not to lacustrine denudation, despite the resemblance of the valley to a lake basin. This part of the paper reads as if it had been written thirty years later.

Cook, 1859.

The next description to be noticed is by my friend Dr. H. Cook, who published a series of papers on the geology of Kalát (Khelat) and its neighbourhood. In one of these, entitled "Geological Report on a part of Beloochistan," published in 1859,[1] there is an account of the geological observations made on a journey through the Bolán Pass. It is unnecessary to recapitulate these, which are for the most part quite correct, at any length. In the hills between Mittri and Dádar conglomerate, sandstone, and clay with veins of gypsum, the whole covered by a thin layer of pebbles, were observed; then after a brief notice of a pass in the main range, 5 miles north of Dádar, the entrance of the Bolán Pass was described through clay, sandstone, and conglomerate. Dr. Cook appears to have looked upon the whole gorge above Kohandiláni as composed of the latter. The fact is that the nummulitic limestone in contact with the conglomerate is so nodular, that it is not easy, without looking at them closely, to distinguish the two, the conglomerate being composed of fragments derived from the limestone.[2]

Dr. Cook noticed the clays and shales below the limestone on the road from Kohandiláni to Kirta, and gave a good description of the road from Kirta to Ab-i-gúm. He observed the conglomerate range

[1] Trans. Med. Phys. Soc., Bombay, No. 5, New Series, p. 105. The paper was printed in the absence of the author, and is full of misprints.

[2] Mr. Griesbach, Mem. G. S. I., Vol. XVIII, p. 80, says that passing through this limestone at night, he mistook it at first for conglomerate; and I, when riding up the pass, had gone some distance beyond the junction before I noticed that I had entered the limestone.

at the base of the hills west of the last named place, the coal at the halting place of Ab-i-gúm (probably that now called Mach, as it was said to be 6 miles from Sir-i-Bolán), the absence of nummulites in the limestones above Sir-i-Bolán, and the thin strata of yellow, red, and white limestones.

In his summary he distinguishes between the sandstones, conglomerates, and clays east of Dádar, and those at the bottom of the Bolán, as so many others have done. The fact is, I believe, that the beds belong to the same system and even to the same subdivision, Upper Siwalik, but the rocks east of Dádar are less disturbed. He did not recognise the pretertiary age of the limestones west of Sir-i-Bolán, although he noticed the absence of nummulites.

Hughes, 1877.

Mr. A. W. Hughes in a work called "Balochistan" (1877) has taken all the information he gives on the geology from Dr. Cook.[1] A few details on the geology of the Bolán Pass are derived from the same authority.[2]

Exhibition of Hippurites, 1879.

In 1879 I exhibited some specimens of *Hippurites* from Siahgai (or Siasgai), 70 miles east-north-east of Quetta, at a meeting of the Asiatic Society of Bengal.[3] These specimens, which were well preserved, were collected by Dr. Oldham, of the 1st Ghurka regiment, and were the first evidence brought forward of the occurrence of hippuritic limestone in Southern Afghanistan.

Geographical papers, 1880-81.

In various geographical papers published after the second Afghan campaign, and especially in those by Sir M. A. Biddulph,[4] Sir R. Temple,[5] and Captain T. H.

[1] Pages 11-14.

[2] Geology, and, I may add, zoology and botany are only incidentally mentioned in Mr. Hughes's works on Sind and Baluchistan, but his remarks are not always correct. For instance, he says (Balochistan, p. 14) that little or nothing appears to be known of the geological features of the mountains in Kalát and Persian Makrán. It is true that very little is known, but still, as he quotes Major St. John as an authority for the geography, and must apparently have derived the details he quotes from the first volume of "Eastern Persian," he must have overlooked the few geological notes in the second volume.

[3] Proc. A. S. B., 1879, p. 202.

[4] Proc. R. G. S., 1880, p. 212.

[5] Ibid, 1880, p. 529.

Holdich,[1] the physical features of the Bolán Pass and the neighbourhood of Quetta are frequently noticed. These features are precisely those which attracted the attention of Hutton, Griffiths, Vicary, and others 30 years earlier; the wide alluvial plains with glacis-like slopes of gravel along their margins, and the long ridges of hills crossed by occasional clefts through which streams find their way to lower levels.

Griesbach, 1881.

By far the most important and complete geological description of the Bolán Pass and the neighbourhood of Quetta, the first indeed made by a professional geologist, is that by my colleague Mr. Griesbach,[2] published in 1881. He traversed the Bolán twice and spent some weeks at Quetta. The state of the country was unfavourable for geological surveying, and he was able to see but little beyond the immediate neighbourhood of the route itself. The systems and subdivisions identified by Mr. Griesbach in the region visited by him are the following (p. 9) :—

Recent	Alluvial and aërial.	
Post-pliocene	Conglomerates, clays, &c.	
Pliocene	1. Manchhars (Siwaliks).	
Miocene	2. Gáj beds.	
Eocene	3. Nummulitic limestone.	1. Nummulitic limestone.
	4. Ranikot group.	2. Sandstones, shales, &c.
	5. Alveolina limestone.	
Cretaceous	6. Deccan traps, &c.	
	7. Upper cretaceous limestones, shales, &c.	
	8. Hippuritic limestone and contemporaneous traps.	

With many of Mr. Griesbach's observations I fully agree, but there are a few points on which I have come to a different conclusion. A considerable portion of the route surveyed by him,—all, in fact, west of the Gházia-band Pass, is beyond the area visited by myself. My opportunities for examining the Bolán Pass and the hills around Quetta, owing to the short period of time that I could devote to them, were less than Mr. Griesbach's, and I should hesitate to express opinions opposed to his,

[1] Proc. R. G. S., 1881, p. 65.

[2] Report on the Geology of the section between the Bolán Pass in Baluchistan and Girishk in Southern Afghanistan, Mem. G. S. I., Vol. XVIII, Pt. 1.

were it not that I have had much better opportunities of becoming acquainted with the rocks of Western India, and especially with the tertiary strata, than he has, and that I think in one or two cases he is mistaken in his interpretation of particular sections. On the relations of beds to each other and on questions of physical geology, Mr. Griesbach is, of course, equally entitled to express opinions with myself, and I can only give my reasons for not concurring with him. The principal points of differences between us are the following: I think (1) that the beds identified by him as Gáj are really Siwalik, and that the identification is founded on erroneous data; that (2) his lowest stage of the eocene system in the Bolán Pass and near Quetta, the *Alveolina* limestone, cannot be accepted as a definite subdivision; that (3) some of the beds classed by him as trappean or trappoid, and upper cretaceous, are not of volcanic origin nor composed of volcanic rocks, and that they are of eocene age; and (4) that he is mistaken in believing that certain upper cretaceous beds occur in the Takátu range near Quetta, and in representing them as thus occurring in fig. 5, p. 29. The above are all, I think, sufficiently important differences to require notice. A few minor points will be discussed in the descriptions of my observations in detail.

Principal points of difference between Mr. Griesbach and writer.

The observations on the geology, in consequence of which I am induced to differ from Mr. Griesbach, will be stated hereafter at greater length. To avoid recapitulation, I shall now only refer to the more important. I have numbered above the four questions that appear to me to require discussion, and shall deal with them in order, beginning with the supposed Gáj beds.

1. The low hills on the western side of Kachhi that are traversed by the old road to the Bolán Pass between Mittri and Dádar consist of clays, soft sandstones, and conglomeratic beds, and contain some gypsum. These beds are (quite correctly, I believe) identified by Mr. Griesbach with certain sandstones, conglomerates, and variously coloured clays, also containing gypsum, which occupy the northern extremity of the Chehiltan or Karaksar

Whether certain beds are Gáj or Siwalik.

range; immediately west of Quetta, and form the greater part of the next range to the westward, the Mashalak [1] range, traversed by the Gháziaband Pass. They are also largely developed in the Pishin valley, north of Quetta.

Rocks near Dádar.

These beds near Dádar and near Quetta are so positively stated [2] by Mr. Griesbach to belong to the Gáj group, that before I give my reason for dissenting, I think it is only fair to say that Mr. Griesbach has never, I believe, seen any Gáj beds, whereas these beds were originally distinguished by Mr. Fedden and myself, and I have examined the whole series of outcrops known between Cape Monze, west of Karáchi, and the northern extremity of Sind. I can see no resemblance between the typical Gáj strata and the beds near Dádar and Quetta; the characteristic rocks of the former are brown limestones, intercalated amongst soft sandy shales, brown to olive green in colour; the latter consist of pale brown sandstones, soft conglomerates or gravels, and clays of various colours. It is true that red and olive clays with white gypsum occur at the top of the Gáj beds at the river Gáj and for some distance north of it, but "these beds pass gradually into precisely similar strata belonging to the overlying Manchhar group," [3] and there is no such striking similarity between the olive clays of the Upper Gáj and the white clays of the Dádar and Quetta hills, even although red beds are intercalated in both cases, as to show that the strata comprising them are identical. Red clays, of one tint or another, and gypsum are found in every tertiary subdivision of Western India, from Upper Siwalik to Ranikot.

[1] This is the name given in the survey map Mr. Griesbach calls the range Dinar. It is not improbable that different names are used for different portions of the range.

[2] That this is the case, is, I think, shown by the following quotations from his report:—

"Near the boundary between Biluchistan and Afghanistan, I first noticed rocks, which I could at once identify with the Gáj group as described by Mr. Blanford in Sind," *l. c.* p. 18.

"The appearance and position of the rocks is so characteristic that there can be no doubt that it is the Gáj group of Sind," p. 20.

The grammar and construction of the last sentence are probably due to some press error but there cannot, I think, be any question as to the meaning.

[3] Mem. G. S. I., Vol. XVII, p. 64. See also p. 91.

But whilst I can see no resemblance between the miocene Gáj strata of Sind and the beds near Dádar and Quetta, the latter appear to be absolutely the same as the pliocene Siwalik or Manchhar rocks of their own immediate neighbourhood. Mr. Griesbach has, I think, quite correctly identified the rocks of the Nári gorge north of Sibi and those of Pir Choki, at the foot of the Bolán, with the Manchhars. Now the sandstones of the Nári and Bolán sections appear to me undistinguishable from those east of Dádar and those of Gháziaband; the conglomerates are similar, and contain the same pebbles, and the clays only differ in the paucity or absence of red and white beds in the Nári and Bolán sections. The presence of gypsum and its mode of occurrence were noticed by Mr. Griesbach himself[1] in the Nári gorge. This gypsum moreover, although its mere presence is unimportant, does, by its mode of occurrence, afford some evidence of connexion between the beds, for in all the localities mentioned, and in places on the western margin of the Bugti hills, the mineral occurs in thin plates, filling cracks that run across the bedding in various directions; and in the Western Bugti hills, where alone, of all the places named, both Upper and Lower Siwaliks occur, this form of gypsum is peculiar to the upper subdivision. The absence of any grey (pepper and salt) sandstones, and of conglomeratic beds containing clay and sandstone pellets, together with the occurrence of nummulitic limestone pebbles, proves, I think, that the beds east of Dádar and those of the Gháziaband Pass near Quetta are Upper and not Lower Siwaliks, and that they belong to the same subdivision as the strata of the Nári and lower Bolán sections.

Mr. Griesbach considers that the position and appearance of the Gháziaband rocks prove them to be the Gáj group. I have shown why I cannot coincide with this view of their appearance. As to their position, it is true that both overlie eocene beds,[2] but the Gáj group

[1] Page 15.

[2] Mr. Griesbach may also mean that Gáj beds come in immediately beneath the Manchhars, and the Dádar beds underlie the Manchhars or Siwaliks of Pir Choki. This last, as will

almost always rests conformably on the Nari (lower miocene or oligocene), whilst the Ghäziaband beds rest unconformably on nummulitic strata (eocene). The position therefore is not identical, although taken alone it affords no evidence one way or the other.

It is evident, however, that one of Mr. Griesbach's chief reasons for identifying the beds of Ghäziaband and Dädar with the Gáj of Sind, is the occurrence of gypsum in the former, and his belief that *gáj* is the Pushtu name for gypsum.[1] I suppose that he insists upon this Pushtu word under the impression that the Gáj beds were thus named in consequence of their containing gypsum. This is not the case; the term, as has been, I think, distinctly stated,[2] was derived from a river in Sind, and this river traverses a country where Pushtu is unknown. I have made enquiries from Europeans well acquainted with Baluchi and Sindhi, and also from natives, but all agree that the name of the river Gáj is of unknown signification. Moreover, so far as I could ascertain, *gáj* is not the Pushtu for gypsum, nor could I learn that any such word exists in Pushtu.[3]

The Pushtu name for gypsum.

be shown hereafter, is rather doubtful, but as the Siwalik beds are many thousand feet thick (there can scarcely be much less than 7,000 to 8,000 feet exposed in the Näri section), the Dädar beds might well underlie those of Pir Choki, where the whole thickness is not exposed, and yet belong to the Siwalik system.

[1] Thus he says (p. 19) of the Dädar beds: "The existence of numerous masses and irregular beds of gypsum (Pushtu: gáj) at once suggested the identification with Blanford's Gáj group. At page 21 and page 59 he repeats the statement that gáj is the Pushtu for gypsum.

[2] Rec. G. S. I., Vol. IX, p. 9. Mem. G. S. I., Vol. XVII, p. 53.—Manual of Geology of India, p. 463.

[3] Two words were given to me by different people as the Pushtu for gypsum. Mr. Ingle, the Assistant Political Agent at Quetta, made enquiries amongst the native employés, and was informed that the Pushtu word used was *askhár*. The head man of Mehtarzai village, close to the Ghäziaband Pass, and to places whence the mineral is procured for building purposes, called it *záwé*. Both ignored the word *gáj*.

I am indebted to Sir O. B. St. John, who had noticed Mr. Griesbach's mistake, for the following very probable explanation. There is a Persian word *gach* (pronounced to rhyme with *such*), which means either gypsum or plaster made from burnt gypsum (plaster of Paris in fact). Such plaster is used very largely in Persia and Afghanistan instead of mortar, and the Pushtu builders, who have probably derived the art of building with plaster from the Persians, use the Persian term for that material. Mr. Griesbach must, I think, have confounded the two words *gach* and *gáj*.

Whether the "Alveolina limestone" forms a definite stage.

2. There is, I believe, neither in the Bolán Pass nor near Quetta, any definite stage or subdivision that can be called the *Alveolina* limestone at the base of the eocene. *Alveolinæ*, like nummulites, are found throughout the system, from top to bottom, in places. Thus at Spintangi, on the Harnai route, and also at Tang on the road from Quat-Mandaj to Thal-Chotiali, there is a thick band of eocene limestone abounding in *Alveolinæ* and *Nummulites*. This band of limestone is near the top of the system, there being only 500 to 1,000 feet of shales overlying. Again, at a spot in the Bugti hills, at the western extremity of the Zen range, north-east of Sháhpur, *Alveolinæ* abound in the uppermost eocene bed together with *Nummulites*. There is, in this last case especially, no reason to suspect any removal of higher eocene beds by denudation, the overlying strata, Lower Siwalik, being to all appearance conformable. On the other hand both *Alveolinæ* and *Nummulites* are often found in beds at or near the base of the eocene. I did not myself notice *Alveolinæ* (although I found *Nummulites*) in the beds beneath the eocene (Mach) shales (Ranikot group of Griesbach) near Sir-i-Bolán, but this is of trifling importance; the distribution of these *Foraminifera* is far from uniform, and if two of us examined the same bed at places a few yards apart, one might easily find *Alveolinæ* and the other none. The point I wish to insist upon is, that to subdivide the eocene system, in descending sequence, into nummulitic limestone, Ranikot beds and *Alveolina* limestone is not correct so far as my knowledge extends, because the *Nummulites* are not confined to the upper subdivision nor the *Alveolinæ* to the lower, and because, so far as I have seen, there is no distinct band of limestone, whether characterised by the abundance of *Alveolina* or not, of sufficient importance to be distinguished as a primary subdivision or stage, either in the Bolán Pass or near Quetta, at the base of the eocene system. For

I have not entered into the question whether, if *gáj* really were the Pushtu name for gypsum, the coincidence would be a valid reason for classing the gypsiferous rocks near Quetta with the Gáj group of Sind, because that is a matter on which I think any geologist can judge for himself.

reasons to be given hereafter, I should prefer not to use the term Ranikot group for the beds of the Bolán, but this is of small importance, as I quite agree that the two may be of the same or nearly the same age.

Whether certain beds near Quetta are of cretaceous age and contain volcanic material.

3. The upper cretaceous beds near Quetta are thus classified by Mr. Griesbach (p. 34), in descending order:—

6. Passage beds: shales and limestones.
5. Liver-coloured shales and grits, trap.
4. Hard dark limestone.
3. Red, white and variegated shales and argillaceous limestones.
2. Hard, grey limestone; *Inoceramus*, corals.
1. Hippuritic limestone.

A description of the section west of Kari (at the northern end of the Chehiltan range), from which the above classification is deduced, is given on the next page (35), and two figures of sections through part of the range on page 37. Some details of one of these sections from my observations will be found in a subsequent page of the present Memoir (in Chapter V).

I believe that the two uppermost subdivisions, 5 and 6, are eocene. There cannot, I think, be any doubt about my identification of the beds in Mr. Griesbach's section. I recognised them easily from the figures and description. The division marked 5 is, however, very much thicker than it is represented in the section. I do not quite understand the shales being described as "liver-coloured."[1] All I saw were pale greenish-grey or olive, the common colour of the eocene shales throughout the system from top to bottom. These shales of the Chehiltan range seemed to me to be clearly the same as those seen north of Quetta, at the base of Takátu mountain,[2] where bands of limestone abounding in nummulites and *Alveolina* are intercalated with them. I think too there can be no

[1] By "liver-coloured" I understand a reddish-brown approaching chestnut. The term is commonly applied in this sense to dogs, *e. g.* a "liver-coloured" pointer.

[2] They were considered identical by Mr. Griesbach also.

reasonable doubt that the shales with coal classed by both of us as eocene at Mach, near Sir-i-Bolán, are the same strata. If this is the case, it is evident that both 5 of the section near Quetta and the overlying "passage beds" 6 must be eocene.

With regard to the presence of trap in No. 5, I could find none either at the section west of Quetta or to the northward. At the former locality trap is not absolutely said to occur; Mr. Griesbach's words (page 35) are: "the shales are evidently made up of trappean materials." At the base of Takátu the same bed is called "trappoid" (page 36), and in the figure 5, page 29, it is entitled "trap band." In neither locality could I find any volcanic rock or any evidence of detritus derived from a volcanic formation, and I carefully examined some coarse grits and conglomeratic beds at both places. The shales at both localities, and in many others where the same beds are found, weather at the surface into a powdery mass, which has an unquestionable resemblance to decomposed basalt,[1] but they are, I believe, a form of marine sediment coloured by some silicate of iron protoxide.

Trap of Bolan.

The trap in the Bolán I did not myself see. Mr. Griesbach looks upon it as representing the shales No. 5 near Quetta, but, from the description that he gives, the horizon at the Bolán must, I think, be lower than that of the Quetta shales. If I understand his description at page 39 correctly, the shales with which he says that he found the trap associated between Darwáza and Dozán can only be the limestone shales so well seen at Dozán; and these are, I think, clearly the same as No. 3 of Mr. Griesbach's section near Quetta, not the supposed trap bed No. 5.

It is not improbable that the supposed existence of a distinct band of *Alveolina* limestone at the base of the eocene has misled Mr. Griesbach as to the position of the beds west of Quetta. At page 35, he writes: "a small stream.....has exposed a good section from the lower eocene

[1] The Talchirs of Central India and Western Bengal are of nearly the same colour, and I have known them in two separate instances to be mistaken for trap by geologists of experience.

Alveolina limestone into the *Inoceramus* limestone," and he commences his description of the section thus: "*overlying beds, Alveolina limestone.*" It is true that in the figured section, page 37, no *Alveolina* limestone is shown. If, however, as his remarks imply, he found limestone with *Alveolina*, his mistake, or what I consider his mistake, in classing the shales and limestones No. 6, and shales and grits No. 5, as cretaceous instead of eocene, is explained by his supposing that there is a definite band of *Alveolina* limestone at the base of the eocene.

Whether cretaceous beds occur at base of Takátu.

4. Takátu hill north of Quetta, so far as I could ascertain, is entirely composed of eocene rocks; the upper portion of limestone with nummulites, and the lower of shales with which bands of nummulitic limestone are intercalated. I spent a day in examining the base of the hill between the road to Pishin and that to the Harnai Pass, and I marched through the latter, so that I saw the whole of the south-eastern and southern side of the hill. I was unable to find either the "variegated flags" or "*Ostrea* limestone" represented on figure 5, page 29, of Griesbach's report. If they occur at all[1] and I have very little doubt they do, they probably crop out in the hills south-east of the Harnai road, along the south-eastern side of the ridge called Nar on the Topographical Survey map. The "trap bandh" of Mr. Griesbach's section is, as already stated, the upper part of the eocene shales, and appears to me not volcanic. One result is that the boundary between cretaceous and eocene rocks south-east of Takátu, if my views are correct, must be drawn about 5 miles further to the south-east than it is represented in Mr. Griesbach's map.

Additions made by Mr. Griesbach to geological information.

In concluding this criticism, and to prevent its being supposed that I have only objections to urge to Mr. Griesbach's work, it is right to point out the important additions made to our previous knowledge by his observations. The wide

[1] To account for my not having seen them, I must plead that my visit to Quetta was not for the purpose of mapping the country, and that my time was very limited, whilst, misled by Mr. Griesbach's accounts, I lost the only day I could spare in hunting for the passage beds at the place where he represents them as occurring along the base of Takátu.

extent occupied by the cretaceous limestones in Southern Afghanistan, the remarkable association of granitic rocks with these limestones, and the similarity of this association to occurrences of the same kind amongst contemporaneous strata in Hungary are most valuable geological observations. The resemblance of the sandy and shaly type of eocene strata to the "flysch" of Central Europe is very interesting. And although I have been obliged to dissent from the interpretation of certain sections represented in Mr. Griesbach's figures, it is only fair to say that many of his plates are not only correct, but good representations of the geology. I may cite as instances Plates I and IV, it being, however, understood that I do not accept the names given to some of the strata in the latter case.

Papers on Bugti Hills.

I am acquainted with only a single description of the rocks seen in the Bugti hills. Few geological papers on India have, however, become more widely known than Captain Vicary's "Geological Report on a portion of the Beloochistan hills," originally published in the "Quarterly Journal of the Geological Society of London,"[1] thence copied into the "Calcutta Journal of Natural History,"[2] and again reprinted, som years later, by Dr. Carter in the "Geological papers on Western India."[3] A summary of the paper and a copy of the section were also given by D'Archiac and Haime in the "Animaux fossiles du groupe Nummulitique de l'Inde."[4]

Vicary, 1846.

The country traversed and described by Captain Vicary extends from the desert plain north of Jacobabad (a town that had no existence in 1846, when Captain Vicary's report was published) to the hills near Dera (Deyrah) on the confines between Bugti and Mari (Murray) territory. Seven ranges parallel to each other are enumerated and represented on the section.[5] These are the east and west ridges of the

[1] Vol. II, 1846, p. 260.
[2] Vol. VII, p. 365.
[3] Page 521.
[4] Pages 169-171.
[5] The route followed by Captain Vicary is evidently that from Jacobabad to Dera by Shahpúr given in Hughes' "Balochistan," page 277.

Bugti country, and most of those mentioned by Captain Vicary are easily traceable. The southernmost, consisting of sandstone, near the desert, is evidently that near Uch, Goránári, &c., formed by low rises of Siwalik strata. The second, also of sandstone, and traversed by the "Jullock Pass"[1] is the well marked range of Siwalik sandstones, marls, &c., that extends along the southern side of the nummulitic anticlinal known as Zen or Zin, which itself is the third range. The fourth is, I think, a part of the same range as the third, Captain Vicary, who drew the section from memory, having forgotten or misunderstood a slight curve in the strike east of Kúmbi (Coombie). The fifth range, the conglomerate of the Dera (Deyrah) valley, is the Upper Siwalik conglomerate ridge along the north side. The sixth range or Traki (Trukkee) is the nummulitic limestone range north of the Dera valley, and the next ridge to the northward, that called "Murray hills," is doubtless the range north of Traki, crossed by the road to Káhan, in the Mari country, at the Naffusak Pass.

Most of Vicary's observations are good, except that he appears to have repeatedly mistaken the concretionary structure so often seen in ferruginous clays, marls, and sands for an effect of calcination, and to have been induced to suppose that the richly coloured beds of the Lower Siwaliks afford evidence of volcanic action (pp. 262, 265). He also thought he saw the effects of volcanic agencies at Uch (Ooch) amongst Upper Siwalik beds, and at Duzd Kushtak (Doza Khooshtie) in nummulitic limestone. So far as the localities have been examined, there appears no reason for supposing that the phenomena observed have any connection with igneous action.

The remarkable clefts serving for drainage, in the surface of the nummulitic limestone ranges, were not likely to escape the notice of so acute an observer as Vicary, who attributed them entirely to fissures produced by the upheaval of the limestone. Some notes on these clefts and gorges will be found in the next chapter on Physiography, where a different view is taken of the manner in which they originated.

[1] Unless this is the Lalli Pass between Zurúni and Zen-ka-Kumb, I cannot recognise it.

Amongst the most valuable of Vicary's discoveries was one of which the importance was scarcely suspected until the examination of the Sind Manchhar (Siwalik) beds. This was the occurrence of mammalian and reptilian bones and of mollusca, in the beds above the nummulitic limestone, on both sides of the range of hills south of Dera. The specimens obtained by Vicary appear never to have been examined, but when it was found that the fragmentary mammalian remains found in the Lower Manchhar beds of Sind belonged apparently to an earlier age than the typical Siwalik fauna, it was naturally suspected that the bones, said by Vicary to be found in such abundance in the Bugti hills, would also be the remains of the more ancient epoch. This has proved to be the case. The shells referred by Vicary to *Paludina* and *Cardium* have also been found again; the first genus was correctly identified, but the supposed *Cardium* proves to be a curious form of *Unio*, very like a *Cardium* in form and with strong radiating ribs. As will be shown in the sequel, these mollusca are of peculiar interest, and their association with the mammalian bones has served to show more clearly than ever the difference in age between the Lower Manchhar or Lower Siwalik beds and the typical fossiliferous Upper and Middle Siwaliks at the base of the Himalayas.

Papers on Sulemán range.

Vigne, 1840.

With the exception of Mr. Ball's paper, as already mentioned, the published contributions to our knowledge of the hills along the western frontier of the Deraját are excessively meagre. Vigne traversed the Gomal Pass in the northern part of the province, and recorded the occurrence of mountain limestone[1] and of ammonites.[2] It is possible that his supposed mountain limestone, like Fleming's, was really of later age, but it may have been carboniferous, for it is evident that a change occurs in the rocks, and in the character of the range itself, north of the Takhti-Sulemán.

In a letter from Dr. Fleming[3] to Sir R. I. Murchison, "on the

[1] Personal narrative of a visit to Ghazni, Kabul, and Afghanistan, 1840, page 80.
[2] *Ibid*, p. 81.
[3] Q. J. G. S., Vol. IX, p. 346.

Geology of part of the Sulemán Range," published in 1853, there are a few notes on the rocks forming the outer ranges near the plain of the Deraját. The "belt of boulder deposit" separating the "alluvial desert tract" from the "Sulemán ranges" is noticed, and also the derivation of the boulders from the rocks of the hills. The conglomerates forming the outer range are said to be identical with those of the Siwalik strata in the Salt Range, and the underlying sandstones are referred to the same system.

Fleming, 1853.

Dr. Fleming went about 3 miles up the Sunghur (Sangarh) Pass and found nummulitic limestone beneath the Siwalik sandstones, &c. The beds dip east, and he suggested that the main range forms the reverse slope of an anticlinal. It proves on examination to be a second anticlinal, the nummulitic limestones seen by Dr. Fleming forming the axis of the eastern convexity, and a synclinal, occupied by higher tertiaries (Siwalik, &c.), intervening between the two.

One remark of Dr. Fleming's proves to have been a mistake. He states that he found boulders of *Productus* limestone (the carboniferous limestone of the Salt Range) in several water-courses, and in a note at the end of the paper, he is said to have found "boulders of white quartzite and *Productus* limestone at the mouth of the Vadur or Vidore (misprinted Vidone) Pass opposite Dera Gházi Khán. The occurrence of carboniferous limestone in the Sulemán range was consequently mentioned in the "Manual of the Geology of India"[1] on Dr. Fleming's authority. It is evident, after the examination of the range, that the occurrence of carboniferous limestone is extremely improbable, no trace of any beds older than cretaceous having been detected in the Vadur and Sangarh Passes, and there can be very little doubt that the limestone supposed by Dr. Fleming to be *Productus* limestone was really the dark cretaceous limestone of the Sulemán, and that his white quartzite was the hard upper cretaceous sandstone.

Erroneous account of occurrence of *Productus* limestone.

[1] Pages 486-491.

Raverty, 1859.

Lieutenant H. G. Raverty, in "An account of the mountain district forming the western boundary of the Lower Deráját, commonly called Roh, with notices of the tribes inhabiting it,"[1] gives some interesting remarks on the physical geography of the ranges.

Stewart, 1860.

The two papers next to be noticed refer to a portion of the Sulemán range farther north than the area examined by [illegible], but they are very interesting, because they show that a complete change takes place in the geology near Bannú, and that metamorphic rocks, and perhaps some palæozoic or lower mesozoic beds, appear from beneath the tertiaries. In the Proceedings of the Asiatic Society of Bengal[2] for July 1860, there are printed some extracts from letters written to Dr. T. Oldham by Dr. J. L. Stewart, who accompanied the 14th Bengal Infantry on the expedition led by Brigadier (afterwards Sir N.) Chamberlain into the Waziri country. The route followed led north-west from Tàk (Tánk) to Kanigoram, thence for some distance northward. Dr. Stewart records having passed over soft sandstones and conglomerates (Siwalik) and then over calcareous strata, red and greenish disintegrating beds, sandstone, &c. (nummulitic), which extended to beyond the Barrara Pass. Farther to the westward, near Kanigoram, slaty beds, contorted and wavy in places, were found, with thin sandstones. These may either be eocene beds somewhat disturbed and having the flysch-like aspect, or more ancient deposits. Vast quantities of granitic (probably gneissic) detritus were observed, showing that metamorphic rocks probably occur at no great distance.

Verchere, 1867.

Dr. Verchere, who accompanied the same expedition, gave a somewhat more systematic account of the country in his paper "On the Geology of Kashmir, the Western Himalaya, and Afghan Mountains."[3] He says that the expedition traversed the plateau of Rusmuk at an elevation of 7,000 feet, and that the main range to the westward is composed of "volcanic, trappean,

[1] J. A. S. B., Vol. XXVI, p. 177.
[2] J. A. S. B., Vol XXIX, p. 314.
[3] J. A. S. B., Vol. XXXVI, 1867, Pt 2, p. 18.

and metamorphic rocks," of which pebbles are brought down by the torrents. The lower hills are said to consist of miocene (Siwalik, probably pliocene) sandstone and conglomerate, resting upon "nummulitic limestone, slate and shale," and beneath the latter flesh-coloured limestone, supposed to be old coral reefs, and referred with some doubt to the oolitic period. At one spot the supposed coral reef limestone was found resting on red marls and gypsum, containing quartz crystals with pyramidal terminations at both ends, and the same crystals are said to be found in the gypsum associated with rock salt and red marl at Mári and Kálábágh where the Salt Range crosses the Indus.

In the general section G[1] attached to Dr. Verchere's paper, miocene (*i.e.*, Siwalik), nummulitic, jurassic and "saliferien"[2] beds are shown to be repeated several times in the hills west of Bannú, but in so peculiar and irregular a manner as to render it probable that the section cannot have been clearly understood.

Ball, 1874.

My colleague Mr. Ball visited a reported coal locality in the Luni Pathán country, west of the Sulemán range, in company with Captain (now Sir R.) Sandeman, and described the geology seen on the route across the range in 1874.[3] The paper was illustrated by a geological map and section, which not only gave a good idea of the geology, but added greatly to our knowledge, for no geologist had ever traversed the Sulemán range before. Mr. Ball's route ran nearly due west from Dera Gházi Khán past Sakhi Sarwar, and he ascended the range by the Siri Pass.

The beds traversed were classified as recent, pliocene, miocene, and eocene. The strata referred with some doubt to pliocene were the conglomerates at the top of the Siwalik system, and there is now no doubt that the age was rightly assigned. The appearance, at the western

[1] J. A. S. B., Vol. XXXV, Pt. 2.

[2] Mr. Wynne, Mem. G. S. I., Vol. XVII, p. 218, shows that some of the beds west of the Indus, referred by Dr. Verchere to his "saliferien," are jurassic. It is impossible to say whether this is the case in the Wasiri country. The peculiar character of the rocks in this country north of the Gomal Pass render Vigne's note on the beds seen in the pass very interesting.

[3] Rec. G. S. I., Vol. VII, p. 145.

extremity of the Siri Pass, of marked unconformity between the conglomerates and the lower members of the Siwalik system is probably, in great measure at all events, deceptive, and due to an abrupt change of dip, but at the same time it is so precisely like an unconformable junction that any one who, like Mr. Ball, only traversed the pass, and did not trace the relations between the beds to the northward and southward, would almost necessarily conclude that the conglomerates had been deposited against the inclined beds of sandstone, clay, &c. The subdivision of the strata below the conglomerates was also impossible to any one merely traversing them. The beds classed as miocene by Mr. Ball are partly, in all probability, of that age, partly newer. His belief, that not only the nummulitic limestone, but also the underlying shales and sandstone, amongst which some thin beds of coal occur, are of eocene age, is entirely in accordance with the observations since made on similar beds elsewhere throughout the western frontier of India.

The repetition of the eocene rocks by alternating anticlinals and synclinals west of the Sulemán is precisely similar to the behaviour of the same beds in the country traversed by myself further south, and appears to indicate that a very large area is covered by these strata, whilst Mr. Ball's section adds another instance of the inconstancy in development of the nummulitic limestone, which he found 1,000 to 2,000 feet thick in the hill ranges to the west of the Sulemán, whilst to the eastward only a few feet occur. The white sandstones noticed by Mr. Ball at Han-ki-der and on the peak of Ek Bhai, both situated at the crest of the Sulemán, are probably cretaceous, as will be shown hereafter. The eocene coal, though of good quality, proved to occur in seams too thin to be worked with advantage. Some additional details will be found below as to the sulphur of the Bozdár country.

The last two papers to be mentioned refer to a tract which, like the Waziri country described by Drs. Stewart and Verchere, is, with the exception of one pass, not included in the area recently examined by myself. These papers are by Lieutenant R. C. Temple, and give an account of the country north of the

Temple, 1879.

Harnai Pass, and of the Mari country, traversed by the second column of the Thal-Chotiali Field-Force between Pishin, north of Quetta, and the Deraját close to Harrand. One of these papers was published in England;[1] the other, entitled "Notes on the formation of the country passed through by the 2nd column Thal-Chotiali Field Force," appeared in India.[2] In the first the geological formations noticed are briefly alluded to and a note is added on the specimens collected, which were examined in the Geological Survey Office, Calcutta.[3] The fossil shells obtained were tertiary, and specimens of syenite, diorite, and earthy amygdaloid occurred, besides sedimentary rocks.

The second paper contains numerous geological details, but the majority of them are either petrological, or else merely record the occurrence of fossils, without specifying what the fossils are. Some doubt must exist as to the accuracy of the rock nomenclature, for the only portion of the route known to me, the Cháchar Pass, is said to consist of "a series of valleys and mountain ranges of more or less breadth, all of limestones, soft and hard, and of all colours." I found very little limestone in the Cháchar Pass, nearly all the rocks are sandstones, shales, and clays. It is therefore a question whether the schists and gneiss said to occur elsewhere on the route are correctly named. So far as the specimens afford information, it is probable that the ground traversed is principally composed of eocene strata, whilst the syenite, diorite, and other plutonic rocks may very probably have been associated with hippuritic limestone, which has been shown by Dr. Oldham's specimens, already noticed, to occur near Mount Siasgai on the route in question, and which probably extends for some distance. The association of syenite and of basalt with hippuritic limestone west of Quetta has been recorded by Griesbach, and I found a basaltic formation intercalated in the cretaceous beds of Kach and Amadun, about 40 miles west of Siasgai.

[1] Jour. R. G. S., 1879, p. 190.

[2] J. A. S. B., Vol. XLVIII, 1879, Pt. 2, p. 108.

[3] I recollect seeing these specimens in Calcutta. They were such as are frequently collected by travellers, and although they afforded some information as to the prevalent rocks, they were insufficient to furnish more than a vague idea of the geology.

Lieutenant Temple in both papers has noticed the remarkable slope of gravel on the margins of the plains, and attributes it, rightly I believe, to the disintegration of the hill rocks, and to fragments being washed down the slopes.

CHAPTER II.

PHYSIOGRAPHY.

General curve of hill ranges.

As may be seen by a glance at the map, the hills beyond the British frontier from the north-western extremity of Sind to Dera Gházi Khán are arranged in a very deep sigmoid curve. From the northern extremity of the Khirthar range west of Shikárpúr to the mouth of the Bolán (an area that, as already mentioned, has not been surveyed geologically),

Ranges west and north of Kachhi.

the general direction is north and south, but north of Dádar, at the entrance of the Bolán Pass, there is a change, and the general strike of the rocks, to which the ranges of hills are parallel, north of the Kachhi or plain around Sibi, Dádar, Gandáva, &c., is nearly north-west—south-east varying to west-north-west—east-south-east. This general direction prevails to the north-west as far as the neighbourhood of Quetta, and to the eastward far into the Mari and Bugti hills. The change in strike, so far as the imperfect observations hitherto made show, does not seem to be attended by any great amount of disturbance, the rocks in the Bolán, and especially the softer beds, are somewhat contorted, and the dips are naturally irregular and variable, but the shales are soft and present no approach to the induration that appears in the same beds to the west of Quetta.

Bugti Hills.

Passing eastward into the Bugti hills the strike becomes east and west, and in the southern part of the hills, north of Jacobabad, the dips are very low, and indicate a passage to the conditions prevailing in the almost undisturbed eocene beds seen further south on the Indus around Sukkur and Rohri. Further

east, at the south-western extremity of the Punjáb, the east and west ranges of the Bugti hills curve round, and the Sulemán range runs, first north-by-east, then due north, parallel to the Indus river, along the western frontier of the Deraját. Some hardening of the shales and sandstones is seen about the place where the change in direction takes place.

Sulemán range.

The ranges near the Bolán Pass are somewhat irregular in direction and structure, and so are some of those around Quetta. Two of the latter, Takátu and Zarghún, both composed of nummulitic limestone, rise to a height of more than 11,000 feet above the sea. Many of the ranges of the Mari and Bugti hills, and some of those near the Harnai route, are simple anticlinals of nummulitic limestone, like the northern and southern extremities of the Khirthar (but not the greater part of that range), and several of the ridges in Southern Sind. The range running from north-west to south-east, north of the Harnai route, from the Chappar rift to beyond Harnai, appears to be one of these anticlinals, and it rises to an elevation, as recorded on the Topographical Survey map, of 11,400 feet north of Sháhrág. The ridges of the Bugti hills are lower. The main range of the Sulemán, as far north as it was examined, is an anticlinal of lower eocene and cretaceous rocks; it rises to an elevation of over 5,000 feet close to its southern extremity, and to a somewhat greater altitude farther north; two peaks, Ek Bhai and Saronk, to the westward of Dera Gházi Khán, being marked on the map as 7,400 and 7,600 feet high. Along the eastern side of the Sulemán are a number of low ridges, more or less continuous, parallel to each other and to the main range, and formed by the outcrop of the harder bands occurring in the eocene and newer tertiary beds. In this respect there is much similarity between the Sulemán and the Khirthar, but, as has already been shown, there are important differences in the tertiary subdivisions represented, and the Sulemán itself is composed of beds lower in position than those found in the Khirthar. The ranges of hills in the country west of the Sulemán appear in many cases to be anticlinal ridges.

Geological structure of ranges.

Valleys and plains.

Between the different ranges of hills there are broad valleys and plains at a considerable elevation above the sea, an elevation that increases with the distance from the foot of the hills up to nearly 6,000 feet around Quetta, and 4,000 to 5,000 feet west of the Sulemans. The valleys and plains present the characteristic appearance of the central Asiatic plateaus; they are bordered by similar slopes of detritus derived from the hills, and they expand in places into open depressions, the surface of which is composed of fine soil, sometimes sandy, and due most probably to subaërial accumulation.[1] Owing to the paucity of the rainfall, both hills and plains are, as a rule, very sterile.

Streams.

The streams are very small and unimportant in themselves, but they possess a curious geological interest from the circumstance that their course is frequently at right angles to the hill ranges, and that many of them traverse gorges cut through anticlinal ridges. Two instances may be especially noted, the "Chappar rift," as it is called, on the Harnai route, and the gorge by which the Kaha traverses the Sulemán west of Harrand. In the first case, the stream draining all the valleys around Kach and Kawás, north-east of Quetta, cuts its way, just below a military encampment known as Mángi, through the anticlinal range of nummulitic limestone that, as already mentioned, rises to an elevation of more than 11,000 feet north of Sháhráig but is comparatively of small size at the Chappar rift. So narrow is the entrance of the gorge from the north that no passage can be seen; it appears as if the stream were entering the side of the hill. The gorge is about 2 miles long, and the sides are several hundred feet high at least.

Gorges or clefts.

Chappar rift.

[1] For a description of similar plains in Persia, see Q. J. G. S., Vol. XXIX, p. 468; Eastern Persia, II, pp. 450, 465; and Proc. R. G. S., 1881, p. 79; also Tietze, Jahrb. k.k. Geol. Reichsanst., Vol. XXVII, 1877, p. 341.

The Afghan plains have been described and their physical features discussed by Lord, J. A. S. B., Vol. VII, p. 521; Griffith, J. A. S. B., Vol. X, p 308; Hutton, Calc. Journ. Nat. His., Vol. VI, p. 362; and Griesbach, Mem. G. S. I., Vol. XVIII, pp. 10, &c.

The Kaha channel is even more remarkable, for not only is it of great depth, certainly more than 3,000 feet, but it is cut through excessively hard sandstone for a considerable portion of the way.[1] Through it the drainage of a very large tract of country west of the Sulemán range finds an outlet, and the quantity of water brought down after heavy rain must be very great. At the same time, it appears remarkable that the stream should traverse the highest range in the country, instead of making its way across lower ground to the southward, especially as that lower ground is composed, for a considerable depth at all events, of much softer rocks than those cut through in the Sulemán range.

Kaha gorge.

These two examples suffice to illustrate a phenomenon which is no novelty to geologists, and especially to geologists in India. Something similer, but on a gigantic scale, occurs in the Himalayas, and has been explained by Mr. Medlicott,[2] whilst Mr. Wynne has called attention to the peculiar manner in which rivers traverse the Salt-range of the Northern Punjab.[3] Other instances might easily be quoted, and in fact the occurrence in one form or another is common. It requires notice, however, because the clefts formed in the nummulitic limestone are so remarkable that no observant traveller can fail to be struck by them, and because the usual explanation, that such clefts are caused by dislocation,[4] or that they are cracks and fissures in the rocks, produced during the elevation of the ranges[5], does not appear to be in accordance with the evidence.

Popular explanation of clefts.

[1] A section of the beds is given in a subsequent part of this report.

[2] Manual of the Geology of India, p. 675.

[3] Mem. G. S. I., Vol. XIV, p. 46, and Vol. XVII, p. 11 (321).

[4] This apparently is my colleague Mr. Griesbach's view (*l.c* p. 4), as he writes: "Dislocations, mostly vertical to the strike of the ranges have prepared the course (in the first instance) for rivers, as for example the Bolán, the Nári, &c." I can only say that I saw no evidence of dislocation in either of the cases quoted, and, so far as my observation has extended, it is a very rare exception, at all events in Western India, for a river gorge to correspond to a line of fracture in the rocks.

[5] Thus in Sir R. Temple's paper entitled "The highway from the Indus to Candahar," Proc. R. G. S., 1880, p. 540, he says: "From some volcanic forces in geological periods, there have been great chasms and rents formed in this wall" (the mountains of the frontier).

* In support of the fissure theory, it is urged that the salient angles on one side of such clefts correspond to re-entering angles on the other, and that this shows that the two sides were formerly in contact.[1] But running water commonly cuts a more or less zig-zag channel, and as the sides of the ravine are denuded by the action of rain, the angles originally formed by the stream, although modified, are not obliterated. Either the whole surface of the slope is removed uniformly, or there is a tendency to exaggerate the salient and re-entering angles, because the latter form channels down which the water runs to the main stream during rain, and are consequently deepened by erosion, whilst the former escape abrasion.

Proof that popular explanation is incorrect

The crucial test is the production of direct evidence that there has been dislocation (*i.e.*, faulting) along the line of the cleft, or that there has been an open fissure. This should be extremely easy, for the rock forming the channel of the stream is generally exposed every here and there. If there be a fault, it could scarcely escape detection, for the beds on opposite sides of the ravine would not correspond. If there has been an open crack or fissure,[2] it must originally have extended to a great depth, far below the present river channel, and must have been filled by fragments before the stream could pass over at its present level. The stream would, in such a case, run over a mass of re-cemented detritus. But it will generally be found that, beneath the loose pebbles, sand, &c., the bed of the stream consists of solid rock, and that where, as is sometimes the case, a calcareous conglomerate is found, this is a superficial deposit, and not a mass filling a deep fissure.

In all the cases where streams cut their way from side to side of a ridge,

* Rivers rise in the plateau which pass through these rents and chasms into the lower valleys."

[1] Vicary, Q. J. G. S., Vol. II, p. 263. I have more than once heard this argument used by other observers.

[2] It should also be remarked that open cracks or fissures, if any such are formed during the process by which rocks assume an anticlinal curve (it is possible that, owing to the pressure, no fissures form), should be parallel to the strike of the beds and to the axes of the anticlinals, and not transverse, as in all cases here noticed.

many other streams cut ravines and gorges, precisely similar in character, but of very inferior depth, from one side only of the water-parting at the crest of the ridge to the valley or plain on the same side. There can be no doubt that the smaller clefts are cut by water, and all that is necessary in order to account for the origin of the great transverse gorges by the same agency is an explanation of the way in which the larger streams began to cut their way through the hills.

All clefts due to erosion alone.

This explanation is that probably the stream once ran at a much greater elevation relatively to the position of the hard rock (nummulitic limestone at the Chappar rift; eocene and cretaceous sandstones and limestones in the Kaha gorge), and that this stream followed nearly the same course as now, but at a higher level and through softer beds. As the latter were gradually denuded away and the hard anticlinal exposed, the stream cut its way through the latter. But the hard rocks resisted the ordinary denudation of the atmosphere and rainwash, whilst the overlying soft clays and sands were carried away until the hard anticlinal remained exposed, just as a skeleton is left when the soft integuments are removed by maceration; the stream alone, by its greater power of erosion, having cut its channel to the depth required for the drainage of the country.

Probable explanation of difficulties in the case of transverse clefts.

It is also probable that the stream, in all the cases mentioned (it certainly is the case sometimes), is older than the disturbance to which the anticlinal is due, and the formation of the latter was so slow that the stream cut its channel deeper *pari passu* with the elevation. In both cases the channel is due to the same cause, the erosion of the stream now running through it.

Valleys probably older than disturbance.

In the neighbourhood of the Chappar rift, there is some further evidence that the course of the streams is of greater antiquity than the disturbance of the strata. The tract of country north of the Kachhi, as already mentioned, consists of ranges of hills having a general west-north-west—east-south-east direction, and these hills, composed partly of anticlinals, partly of scarps, of hard beds, are separated from each other by

broad valleys, often of so great extent as to assume the character of long plains rather than valleys, with the same general direction as the ridges, and corresponding to the outcrops of the softer strata. Had the form of the country been what it now is when the main drainage lines were traced, it is reasonable to believe that all the streams would run along these valleys, whereas the main drainage is across them; each stream, after coinciding with the plain in direction for a few miles, cutting its way through the next ridge to the southward.[1] It is difficult to account for this peculiarity, unless we suppose that the general direction of the streams is of greater antiquity than the disturbance of the rocks and the formation of the present ridges and valleys by denudation.[2]

Natural bridge at Sangsila.

The curious natural bridge at Sangsila in the Bugti hills, of which a figure is given in the frontispiece, is a very interesting example of stream action. A few details concerning this arch of rock will be given on a subsequent page with other notes on the geology of the neighbourhood.

CHAPTER III.

GEOLOGICAL SYSTEMS AND THEIR SUBDIVISIONS.

Area mainly tertiary.

Throughout the area traversed no beds of older age than cretaceous were observed. The greater portion of the country by far is covered with tertiary deposits, through

[1] This is not so conspicuous on the accompanying map as on the ground. The same phenomenon is seen to the westward in Makrán, north of Gwádar. The valleys or plains form a series of terraces, each in turn rising above that to the southward, and separated from it by a range of hills. The streams run across the terraces, not along them. See "Eastern Persia," Vol. II, p. 450, &c.

[2] Since this chapter was written I have received from Dr. Emil Tietze[a] a very important memoir on the formation of transverse valleys. If I understand Dr. Tietze rightly, his views are precisely the same as those above advocated. It is scarcely necessary for me to add that there is a very large amount of literature extant on the subject of transverse valleys, chiefly by continental writers. The theory that transverse valleys are as a rule due to fracture or dislocation has, I believe, been practically extinct amongst the best English geologists for about 30 years. A very good account of the prevalent ideas amongst English geologists may be found in Geikie's Text book of Geology, pp. 371—379.

[a] Tietze "Bemerkungen uber die Bildung von Querthälern." Jahrb. K.K. Geol Reichsanst., Vol. XXXII, pp. 685, 703 (1883).

which, as will be seen by a glance at the map, the cretaceous rocks protrude, within the country examined, only in the neighbourhood of Quetta to the westward, and along the Sulemán range to the eastward.

Variation in cretaceous deposits.

The cretaceous beds in these two not very distant localities differ totally in character, and are in both places perfectly distinct from the formations of the same or nearly the same geological age observed in the Laki hills of lower Sind. The eocene strata are less variable, although there are constant changes in the position and thickness of the limestones. The later tertiary beds are more constant in character.

List of strata.

The following is a list of the subdivisions observed. Owing to the differences in distribution just mentioned, the strata of the neighbourhood of Quetta, including the Bolán and Harnai routes, are placed in a different column from those of the Sulemán range :—

List of Geological Sub-divisions observed around Quetta and in the Sulemán Range.

Systems or major Divisions.	Subdivisions.	Quetta and neighbourhood.	Approximate maximum thickness.	Sulemán.	Approximate maximum thickness.	Geological age.
5. Recent and Post-pliocene.	. . .	Sands and fine loam of plains. Gravels and conglomerates of slopes, &c.	?	Alluvium of Indus valley. Gravels of slopes, &c.	?	*Recent and post-pliocene.*
4. Siwalik or Manchhar.	Upper .	Sandstones, clays, and conglomerates of base of hills and of plateau.	7,000	1. Conglomerates. 2. Sandstones and clays with conglomeratic bands.	2,500	*Pliocene.*
	Lower .	*Wanting* . .	. .	Sandstones, clays, marls, bone beds, &c.	5,000	*Upper miocene.*
3. Nari . .	Upper .	*Wanting* . .	. .	Sandstones, clays, &c.	2,000	*Miocene.*
	Lower .	Brown limestone of Bibi Nání.	?	*Wanting* . .	. .	*Oligocene.*

List of Geological Sub-divisions observed around Quetta and in the Sulemán Range—(continued.)

Systems or major Divisions	Subdivisions.	Quetta and neighbourhood.	Approximate maximum thickness.	Sulemán.	Approximate maximum thickness.	Geological age.
2. Eocene	Upper	Nummulitic limestone.	2,000	Olive clays, shales, sandstones, &c., with a few thin bands of nummulitic limestone.	2,000	Eocene.
	Lower	Olive shales, clays, sandstones, &c. a band of limestone breccia at or near the base.	3,000 P	Coarse brown sandstone with a band of limestone breccia.	1,000	
1. Cretaceous		1 Black compact limestone	200	1. Hard whitish sandstone grit.	1,500	Cretaceous.
		2 Variegated limestone shales.	500			
		2a. Conglomerate of volcanic pebbles Basalt (local)	1,000	2 Dark-grey limestone passing downwards into limestone shales.	1,000 seen.	
		3 Dark grey limestone	1,000			
		4. Pale limestone	500 seen			

Geological observations imperfect.

It should be remembered that the examination of the country traversed was of the most cursory and superficial description, and had not the geology in general been exceptionally simple, no adequate idea could have been gained of the structure. In places, as in the neighbourhood of Quetta, and of a portion of the Harnai route, where the geological features are a little more intricate, further examination is required before the characters and distribution of the formations can be thoroughly understood. The map compiled is simply a sketch without any pretension to exactness in detail; some of the geological boundaries having been inserted on the strength of observations made at a distance of several miles. But with a surface so utterly destitute of any concealment by vegetation, the colour and

appearance of particular beds can be recognised through the clear atmosphere of these dry desert regions at very great distances, and the certainty with which geological boundaries can be traced for miles, if seen from an elevation, would scarcely be credited by geologists who have not had experience of similar areas.

Thickness of beds.

The thicknesses assigned in the preceding table are as a rule mere guesses, and are chiefly intended to show the relative development of different stages and beds. The aggregate given above of about 17,000 feet near Quetta and 21,000 in the Sulemán range is as likely to be too low as too high. The thickness of each subdivision varies considerably.

Cretaceous.

1. *Cretaceous beds.*—As already more than once pointed out, there is a wide difference between the representatives of this system near Quetta and those exposed in the Sulemán range. The former will first receive notice.

Cretaceous rocks of Quetta.

The lowest bed seen by me in the neighbourhood of Quetta is the limestone of the hills due south of Sir-i-áb and about 10 miles south of Quetta itself. These hills consist of an anticlinal of pale coloured, often cream-coloured or pale pinkish-grey limestone, very homogeneous and fine-grained.

Pale limestone.

In the hill range to the east of the Quetta plain, not visited by me, Mr. Griesbach found hippurites[1] in abundance in strata which he considered a little lower than those exposed in the Sir-i-áb hills. The latter are precisely similar to some of the limestone with hippurites found to the westward in Persia. A few hundred feet of this rock are seen near Sir-i-áb, the base not being exposed. Fossils do not appear very common, but they may be more abundant locally.[2]

[1] Mem. G. S. I, Vol. XVIII, p. 36. A section through the hills near Sir-i-áb is represented on p. 37. The relative thickness of the different beds in this section (fig. 8, and also in the upper fig. 7) is not correct, and as the scale of heights is much greater than that representing horizontal distance, the general effect is not exactly the same as that of the rocks *in situ*.

[2] Mr Griesbach found *Inoceramus* and corals in these beds (*l. c.* p. 36), but, as I understand, not in this locality.

Dark limestone.

The next limestone in ascending order is very dark coloured, often black or blackish grey. It is hard and massive, and forms the greater portion of the slopes on the hill ranges east and west of the plain south of Quetta. South-west of Sir-i-ab this dark coloured limestone appears clearly to overlie the paler coloured homogeneous limestone just described. The thickness of the dark limestone[1] is considerable, probably not less than 1,000 feet and possibly more, but time did not admit of any measurement. To the westward higher rocks come in above the dark limestone. To the southward, the same dark cretaceous limestone forms the greater part of the hills on the sides of the Dasht-i-Bedaolat, and is traversed by the road between Dozán in the Upper Bolán Pass and Darwáza or Dasht.

White and variegated limestone shales.

Above the dark massive limestone there is a considerable thickness, probably not less than 500 feet near Quetta, of some very characteristic strata, fine-grained shaly or flaggy limestones and calcareous shales[2] of various colours, chiefly white or cream-coloured, variegated with purplish red or alternating with bands of that tint. No recognisable fossils were found. These calcareous shales are well seen (1) at Dozán in the Upper Bolán Pass; also (2) on the skirts of the hills east of the road between Darwáza and Sir-i-ab, south of Quetta, about 6 or 7 miles north-west of Darwáza; and (3) in the Chehiltan range south-west of Quetta.

Cretaceous beds of Kach and Amadun.

Similar beds are also seen near Kach and Amadun, about 25 miles north-east of Quetta, associated with a great development of basaltic formations, partly detrital, but partly, to all appearance, consisting of solid igneous rock. The latter may be intrusive. The sections will be described in more detail in Chapter VI, in which the observations made on the Harnai route between Quetta and Sibi will be recapitulated. Near

[1] This dark limestone is the No. 2 or *Isocerasmus* limestone of Mr. Griesbach's sections, pp. 34, 35, and of his figs. 7 and 8, p. 37. It is also No. 1 of his Profile 1, plate IV. This profile gives a better idea of the geology than the sections on p. 37.

[2] No. 3 of Griesbach, pp. 34, 35 and figs. 7 and 8, p. 37. No. 2 of Profile 1, pl. IV.

Kach camp, on the road to Gwál, the variegated limestone shales dip at a high angle and appear to underlie a bed of basalt or anamesite, apparently interstratified. The dip is probably reversed and the variegated limestone shales may be the newer formation. Further on upon the same road the variegated limestone shales are distinctly seen overlying a mass of basalt. A few miles further to the north-east from Kach, near Amadun, the limestone shales overlie (apparently underlie, but the dip is again reversed) a mass of conglomerate, probably 1,000 feet thick, entirely composed of rolled doleritic pebbles. This is succeeded in descending order by massive limestone of great thickness, probably the same as the dark cretaceous limestone of the hills near Quetta. The relations of all these beds near Kach to those near Quetta are not absolutely certain, as will be shown presently.

Volcanic rocks

Conglomerate of doleritic pebbles.

The uppermost bed that I refer to the cretaceous system near Quetta is the hard, black, massive, compact limestone[1] above the variegated limestone shales. This bed is admirably seen, and from its dark colour and hardness forms a conspicuous band on the Chehiltan range south-west of Quetta, where the thickness is probably about 150 feet. The same bed, probably rather thicker, is well exposed in the Bolán Pass below Dozán.

Hard, black, compact limestone.

No recognisable fossil was obtained by me from this bed, and the only reason for assigning it to the cretaceous rather than to the eocene system is that in appearance and mineral character it resembles the limestones of the latter much more than those of the former, that it contains no nummulites, and that in the Bolán Pass it underlies beds containing a peculiar limestone breccia which is certainly very close to the base of the eocene system. The black compact limestone was not found near Kach. All the beds near Quetta from the black limestone downwards, appear to be conformable to each other.

The cretaceous rocks of the Sulemán range differ so widely from

[1] No. 4 of Griesbach, pp. 34, 35, Ostrea limestone of sections 7 and 8, p. 37, and No. 3 of Profile 1, pl. IV.

those of Quetta that before leaving the latter a few words on their relations to the rocks of the same age in other parts of Asia are desirable.

Relations of Quetta cretaceous beds.

The two lower beds in the section, the pale-coloured and the dark-grey limestone, are, I think, clearly upper members of the great hippuritic limestone group. This is I believe Mr. Griesbach's view also. Very similar limestones were found by him [1] to form the ranges near Kándahár, and precisely the same rocks, sometimes quite unfossiliferous, but locally abounding in *Hippurites*, are widely exposed in Persia [2] from Karmán to Teherán. To the eastward hippuritic limestone is known to occur at Siasgai peak, 70 miles east-north-east of Quetta, [3] and there is great probability that the cretaceous beds generally are well developed in the ranges north of the Harnai route around Kawás and Chinján. The limestone with *Hippurites* found in the Laki range of Sind [4] may be of the same age, but there, as in the Sulemán range, the whole section is so different that the different stages cannot at present be recognised.

Hippuritic limestone.

The conglomerate of doleritic lava pebbles found near Amadun precisely corresponds to the description given by Mr. Griesbach of similar deposits observed by him west and north-west of Kándahár at Kotal-i-Murcha, Kohkarán, &c., in the range between the city and the Argandáb valley. The beds above the conglomerate, greenish sandstones overlying green and red shales, in the section given by him [5] have some remarkable points of resemblance to those near Amadun, where, above the doleritic conglomerate, variegated limestone shales occur, and over these again the greenish sand-

Doleritic conglomerate.

[1] *L. c.*, pages 39-45.

[2] Eastern Persia, Vol. II, pp. 457, &c.

[3] Proc. A. S. B., 1879, pp. 202: see *ante*.

[4] Mem. G. S. I., Vol. XVII, pp. 17, 133.

[5] *L. c.*, p. 42. "3. A shaly sandstone made up more or less of trappean material.

"2. Bright coloured green and densely red shales with thin sandstone beds of trappean substance.

"1. Conglomerate, coarse and in great thickness almost entirely made up of pebbles of trap, and cemented together by a trappean though calcareous matrix."

[illegible] and sandy shales at the base of the eocene, the latter being precisely the beds which Mr. Griesbach looks upon as formed of trappean detritus near Quetta. But the Kándahár beds are said to be lower cretaceous and inferior in position to the hippuritic limestone. If this is correct, either the beds near Amadun cannot be the same as those near Kándahár, or the identification of the variegated limestone shales with those of the upper cretaceous beds at Quetta is erroneous. The circumstance that, as will be shown hereafter, the eocene beds at Kach near Amadun are unconformable to the cretaceous certainly renders it possible that the latter may belong to a lower and not to the upper subdivision of the system, but it is more probable that the view taken above of the relation between the Kach and Amadun beds and those of Quetta is correct, and that the variegated limestone shale at both places is identical.

Limestone shales.

The white and variegated limestone shales of Quetta do not appear to have been observed further west, unless, as above suggested, they are represented by the green and red shales of Kándahár. This suggestion, however, is merely indicated as possible. There is much more reason to believe that these calcareous shaly and flaggy beds are identical with those observed on the upper Gáj river, west of the Sind frontier,[1] with similar beds found by Dr. Cook[2] at several places south and south-west of Kalát, and with some greenish-white and pale purple calcareous shales seen at Gadáni,[3] on the Baluchistan coast, about 25 miles north-west of Karáchi. In the first-named locality on the Gáj river the limestone shales are in the same position as near Quetta, just below beds of eocene age, and the same is the case, according to Dr. Cook, in the country south and south-west of Kalát. At Gadáni, where the relative position was not ascertained, basalt and dark-grey or blackish limestones were found in the immediate neighbourhood, showing a remarkable resemblance to the association of rocks at Kach near Quetta.

[1] Mem. G. S. I., Vol. XVII, pp 42, 98.
[2] Trans. Med. Phys. Soc., Bombay, 1860, No. VI, p. 100.
[3] Mem. G. S. I., Vol. XVII, p. 189.

The trap noticed by Mr. Griesbach in the Upper Bolán Pass must, I think, as already stated in the first chapter of this Memoir,[1] be associated with the limestone shales.

Relation of volcanic rocks to Deccan traps.

It is highly probable that the upper cretaceous dolevitic rocks near Quetta are of contemporaneous origin with a portion of the Deccan traps. But I am not at all sure that any of the former "represents the trap horizon of Western Sind," although Mr. Griesbach thinks there is no doubt of the fact.[2] The traps of the Deccan appear to extend in age from upper cretaceous to lower eocene,[3] and although I am inclined to class the Quetta volcanic rocks with the former, the trap of Western Sind may perhaps be of very early tertiary age. To this subject it will be necessary to revert presently when discussing the eocene beds.

Boundary near Quetta between tertiary and cretaceous.

The boundary near Quetta, between the cretaceous and eocene beds, is drawn upon undoubtedly imperfect evidence. That the lowest beds referred to the eocene system in the Upper Bolán section, on the Chehiltán range west of Quetta, and near Kach, are tertiary, admits, I think, of little, if any, doubt, and all the limestones beneath the variegated calcareous shales may be, I believe, safely referred to the cretaceous period. The only question is with regard to the variegated limestone shales themselves and the overlying black limestone. The very marked break in character between the latter and the olive eocene shales, and the fact that these olive shales near Kach are distinctly unconformable to all underlying beds, including the limestone shales (the compact black limestone is wanting), besides the points already mentioned, the absence of nummulites in the supposed cretaceous limestone, and its mineral

[1] *Ante* p. 17.

[2] *L. c.*, p 51. In this and numerous other cases it is to be regretted that Mr. Griesbach has expressed himself so confidently as he has done.

[3] Manual of the Geology of India, p. 329. Some recent researches of Mr. Bose, noticed by Mr. Medlicott, Rec. G. S. I., Vol. XV, 1882, p. 5, appear to indicate a rather later age for the lowest Deccan traps. I have gone over the evidence very briefly, but it does not appear to me that sufficient reason has been shown for classing any of the fossiliferous beds beneath the trap at Bág as of later date than the Trichinopoly beds (lower Chalk or Turonian), and they may be Cenomanian. If so, the lower traps are probably upper cretaceous.

character, are opposed to the classification of these rocks as eocene. It should not be forgotten also that Dr. Cook[1] found ammonites south of Kalát, in beds very probably identical with the limestone shales of Quetta.

Cretaceous of Sulemán range.

In the Sulemán range the supposed cretaceous beds comprise two well-marked stages. The lower of these was only observed in the deep ravines cut by streams into the main range itself, and was actually examined in but two localities; the deep gorge of the Kaha stream, west of Harrand, and that excavated by the head waters of the Choti stream, immediately south of the road to Fort Munro, the sanitarium of Dera Gházi Khán. This lower stage consists of dark grey limestones, occasionally sandy or shaly,

Grey limestone and calcareous shales.

passing down into calcareous shales, dark-grey to bluish-grey in colour, and often nodular. The bottom of these was not seen, and the whole thickness of limestone and shale exposed must have been about 1,000 feet in each of the sections examined.

Fossils.

The limestone abounds in indistinct fossils, especially *Foraminifera*, but none were found that could be determined at the time. In the underlying shaly beds, however, two species of *Exogyra*, one or two of *Inoceramus*[2] and a Cephalopod were found. The latter is so poorly preserved that not even the genus can be ascertained; it doubtless belongs to the *Ammonitidæ*, and the last whorl appears to be protracted somewhat as in *Hamites*, whilst the upper whorls may have been free as in some *Turrilites*. All the whorls are transversely ribbed. The *Inoceramus* is a form with concentric ribs and fine striæ parallel with the ribs. The *Exogyræ* are more characteristic. One species is nearly allied to *E. suborbiculata*, Lam., and is also near the well-known *E. columba*, Lam.; the second species is near *E. ostracina*,

[1] *L. c.*, also Mem. G. S. I., Vol. XVII, p. 43.

[2] I am indebted to Dr. Feistmantel for assistance in making out these. In explanation of the very imperfect identification given, it is necessary to explain that the fossils are in Calcutta, whilst this paper is being written in England, and that I was unable to compare the specimens whilst in Calcutta.

Lam. All these species of *Exogyra* are middle cretaceous, and both the *Inoceramus* and Cephalopod are cretaceous rather than jurassic types.

The *Inoceramus* is the commonest and most characteristic fossil; some of the shells found measure 6 inches across, and the two valves often occur together, though wide open.

Hard whitish sandstones

Upon the limestones, apparently conformably, hard sandstones and grits are deposited, about 1,500 feet thick, generally pale coloured, white or whitish, not unfrequently speckled with brown, and occasionally pale-greenish, bluish-green, or purplish. A few thin beds of dark shale occur, but they are infrequent. From their hardness and pale colour, these rocks are very conspicuous, and they form a considerable proportion of the eastern slope on the Sulemán main range. No fossils have been found in them.

No unconformity can be detected between the hard whitish sandstones and the beds above and below them. The limestones beneath are sandy towards the top, and there is in places intercalation of sandstone layers between the uppermost beds.

Relations to other cretaceous beds.

Neither of the stages described above can be identified with any known cretaceous formation. There is not much similarity between them and the poorly developed representatives of the system in the Trans-Indus continuation of the Salt Range, though the soft white supra-jurassic sandstone of Shekh Budín,[1] may perhaps, although greatly dwindled in size, be the same bed as the hard whitish sandstones of the Sulemán range. The sandstone of Shekh Budín has nowhere been observed to exceed 200 feet in thickness, and its relations to the jurassic beds beneath it appear somewhat doubtful, for Mr. Wynne, whilst classing it provisionally as cretaceous, suggests that it may be partly even post-eocene in age.

None of the passage beds between the eocene and the cretaceous in Sind present much resemblance to the hard whitish sandstones of the

[1] Wynne, Mem. G. S. I., Vol. XVII, pp. 79-84.

Sulemán range, and the limestones of the former area are quite different from those of the latter. It is highly probable that the sandstones[1] beneath the *Cardita beaumonti* beds in the Laki range of Sind may be on nearly the same geological horizon, but there is no sufficient evidence for correlation. The only sandstones known in India, so far as I am aware, that distinctly resemble the Sulemán beds in mineral character, are those forming the lower portion of the Bág beds[2] in the Western Nerbudda valley, and especially those exposed on the Deva stream in the Rájpipla hills. But these sandstones, although cretaceous, are probably older than those in the Sulemán range.

Probable age of Sulemán sandstones

The reason for assigning the Sulemán sandstones to the cretaceous system is that, near the bottom of the next overlying stage, the peculiar band of limestone breccia occurs, that, in so many places, appears to mark the base of the eocene. The limestones underlying the hard white sandstones appear to be cretaceous, and the fossils show some resemblance to those of the upper green sand (Cenomanian).

2. *Eocene*.—The eocene beds present no such difficulties as the cretaceous, nor, although their character is very far from uniform, do they vary so widely in different parts of the areatraversed as the under lying beds A fair general description of them is that they consist of olive shales, more or less sandy or calcareous in parts, with beds of nummulitic limestone, varying in thickness and in position, but so developed occasionally as to occupy the greater portion of the whole system, the shales becoming merely subordinate. This is the case in the Bolán Pass and north of Quetta, whilst elsewhere, as east of the Sulemán range, nearly the whole thickness of the system consists of shales; beds of limestone being only found at rare intervals and a few feet in thickness. Soft sandstones are often intercalated with the shales, and in the Sulemán range the lowest part of the whole system is composed of hard brownish and purplish sandstones, about 1,000 feet thick

General description of eocene beds.

[1] Mem. G. S. I., Vol. XVII, pp. 32, 34, 129, &c.
[2] *Ibid*, Vol. VI, pp. 207-312, &c., and Manual, page 295.

amongst which a few beds of shale or of limestone are intercalated. One of the limestone bands close to the base is the very peculiar limestone breccia already referred to somewhat frequently. It consists of dark-grey angular limestone fragments in a somewhat paler limestone matrix. Both fragments and matrix contain small *Nummulites* and sometimes *Alveolinæ*, and no constant difference has been traced between the forms found in the two portions of the rock. This bed does not appear to be more than 30 to 40 feet thick, and it has been observed near Quetta and also on the Sind Frontier, at the Gáj river, as well as in the Sulemán range.

Limestone breccia of lower eocene.

The eocene is, taken altogether, the most important system on the frontier of Western India. In Southern Afghanistan it is seldom, if ever, less than 5,000 to 6,000 feet thick, and it is probably in places as much as 9,000 feet, if not more.

Thickness of eocene.

To show the variation in character of the eocene beds it will be useful briefly to pass them in review from Sind to the Punjab, calling attention also to the change in characters that takes place to the westward.

Variation.

The eocene rocks of Southern Sind[1] consist of the following in descending order:—

Southern Sind eocene.

Strata.	Thickness.
Khirthar limestone.	Variable, not exceeding 500 feet.
Ranikot sandstones, shales, and clays, with bands of brown limestone near the top.	About 2,000.
Deccan trap.	Variable, 40 to 90.
Cardita beaumonti beds. olive shales and limestone.	350 to 450.

[1] Mem. G. S. I., Vol. XVII, pp. 39, 46, 128, &c. The Nari oligocene beds are not here included in the eocene system.

In Cutch the eocene beds above the Deccan trap are thus classified by Mr. Wynne:—

Nummulitic group, white and yellow limestones with marls and sandy beds	760 Feet.
Gypseous shales	100
Subnummulitic group, variegated argillaceous beds highly coloured	100

Mem., G. S. I, Vol. IX, p. 46.

The latter, with the overlying band of basaltic trap, I have hitherto classed as cretaceous.[1] The fauna, however, so far as it has hitherto been examined critically,[2] seems to show that, although there is an admixture of forms with cretaceous affinities, eocene types predominate, and the olive shales agree in mineral character with rocks characteristic of the eocene period in Western India. It appears therefore advisable to class these *Cardita beaumonti* beds as the lowest tertiary; they are perhaps inferior to any known eocene stage found in Europe, for the Echinoderms of the Ranikot beds, as shown by Dr. Martin Duncan,[3] are older in facies than the lowest Echinoderm fauna known from the tertiary beds of Europe and North Africa, whilst the *Cardita beaumonti* beds are 1,500 feet below the fossiliferous Ranikot strata.

Eocene of Khirthar range.

About 60 miles further north than the Laki hills, where the section last quoted was observed, the eocene rocks in the Khirthar range separating Upper Sind from Baluchistan consist of a mass of nummulitic limestone, 1,000 to 3,000 feet thick, resting upon olive and brown shales, clays, and sandstones with bands of limestone, generally containing nummulites, intercalated. In the only place where the thickness could be estimated, on the Gáj river, the section was :—

Nummulitic limestone	1,200
Shales and sandstones, with bands of limestone in places . about	4,000

Bolán Pass.

In the Bolán Pass the section is similar, massive nummulitic limestone above, shales and sandstones, often of an olive colour, below. It is very difficult to estimate the thickness of the nummulitic limestone, and the upper portion probably suffered from denudation before the overlying Upper Siwalik beds were deposited, but the remaining thickness must be at least 1,000 feet in

[1] Manual of the Geology of India, p. 447, &c., Mem. G. S. I. Vol XVII, pp. 32-33, &c.

[2] The corals and echinoderms have been described by Dr. Martin Duncan with the assistance, for the latter, of Mr. Percy Sladen. See Palæontologia Indica, Ser. XIV, Vol. I, Pts. 2-3.

[3] Pal. Ind., XIV, Vol. I, pt. 3, page 99.

places, though perhaps rather less in the Lower Bolán Pass itself between Kohandiláni and Kirta. The limestone is of the usual character, rather massive in general but occasionally distinctly stratified, pale-coloured, usually whitish or light-grey, rarely dark-grey, and often abounding in nummulites and other *Foraminifera*. One variety, described by Mr. Griesbach,[1] has a concretionary structure and simulates conglomerate; this bed is well seen just above Kohandiláni. A similar bed is not uncommonly met with in the nummulitic limestone of Northern Sind.

The lower eocene shales and sandstones in the Bolán Pass comprise several thin beds of coal,[2] particularly well seen about Mach near Sir-i-Bolán, associated with bands of impure limestone containing *Cyprina* and other bivalve shells, *Turritella*, &c. Many of the species have an estuarine facies. Towards the base are some dark-coloured limestones containing *Nummulites* and other *Foraminifera*, one of these beds being the breccia already noticed.

Coal-bearing beds of Mach.

The country north of the Upper Bolán Pass around the great Zirghun mountain has not been examined, but the same arrangement of limestone above and shales below occurs in Takátu mountain north of Quetta, where, however, the thickness of both the limestone and the shale appears greater than in the Bolán, and neither can be less than 3,000 feet in thickness. To these sections it will be necessary to recur presently.

Country north of Upper Bolán Pass.

West of Quetta a great change takes place. In the Chehiltán or Karaksar range south-west of the town, all the upper portion of the eocene system is composed of limestones with shaly and sandy beds intercalated, the whole being very different from the massive limestone of Takátu. At the base, in the Chehiltán range, there are about 1,500 feet of olive shales resting on the black compact upper cretaceous limestone. In the next range to the westward, that of Mashalik (or Dinár), it is probable that the upper limestone

Eocene west of Quetta.

[1] *L. c.*, p. 30.

[2] Mem. G. S. I., Vol. XVIII, p. 22. Rec. G. S. I., Vol. XV, 1882, p. 149.

of Takátu is not represented, the only limestone that I saw is in bands of no great thickness, and similar in character to the beds intercalated in the olive shales forming the lower part of the system, except that it is darker in colour than they usually are to the eastward.[1] The associated shales and sandstones are turned on end and greatly hardened, some being almost slaty. The hardening and contortion, according to Mr. Griesbach,[2] are conspicuous in the much higher range a little further west, known as the Amrán, and crossed by the Kojak Pass on the road to Kándahár. Here also no great bed of nummulitic limestone was observed, although bands of considerable thickness are intercalated. Mr. Griesbach calls attention to the resemblance between these shales and sandstones and the flysch of the Alps.

Relations to beds of Takátu.

There appears every probability that the thick limestone of Takátu, partially broken up into shaly and sandy beds in the Chehiltán range, disappears to the westward, and is replaced by shales and sandstones, precisely as takes place with the Khirthar limestone in South-Western Sind.[3] The "flysch" character of the eocene rocks is highly developed in the western part of Baluchistan, and some of the enormous series of vertical or nearly vertical beds seen between Gwádar and Jalk on the edge of the Sistan desert[4] closely resemble the beds of the Mashalak range west of Quetta.

"Flysch" of Baluchistan.

Eocene east of Takátu.

Passing eastward from Takátu, along the Harnai route from Quetta to the plains, the olive shales, clays, and sandstones of the lower eocene appear to increase in thickness. Some beds of dull Indian red shale or clay are intermixed and become more conspicuous further east. Occasionally bands of limestone, usually

[1] As I have already suggested (Manual of the Geology of India, p. 511), it is not improbable that the nummulitic limestone assumes a darker colour where it has undergone pressure and disturbance; certainly wherever the associated beds are turned on end, hardened, or contorted, so far as I have seen, the limestone is darker coloured than it usually is when but little disturbed.

[2] *Loc. cit.*, p. 32.

[3] Mem. G. S. I., Vol. XVII, pp. 47, 176.

[4] Eastern Persia, Vol. II, p. 461. Jalk is about 300 miles south-west of Quetta.

pale coloured, abounding in *Nummulites* of several species, and often containing *Alveolinæ*, *Orbitoides*, and other *Foraminifera*, attain a considerable thickness. One such band forms the ridge of Nár, 12 miles north-east of Quetta.

Near Kach and Amadun.

The basement beds of the eocene system near Kach and Amadun, about 25 miles north-east of Quetta, are olive shales and sandstones, with some beds of conglomerate, containing pebbles of sandstone, grit, limestone and chert. These beds rest quite unconformably on the cretaceous beds above described, and are overlain by the nummulitic limestone of the Pil range, east of Kach. The junction, it may here be mentioned, is the only instance of unconformity between eocene and cretaceous beds yet observed in the countries adjoining the Sind frontier.

Eocene beds on Harnai route east of Kach.

Unfortunately in the hurry of travel[1] the sections of eocene beds exposed in the hills bordering the Harnai route received but a very imperfect examination. Zarghun, the great range already noticed as lying east of Quetta and north of the Upper Bolán Pass, and which intervenes between the upper parts of the Bolán and Harnai roads, appears to be, like Takátu, formed of a very thick mass of nummulitic limestone overlying the lower eocene shales and sandstones. This nummulitic limestone in the Bolán Pass is the highest eocene bed seen. In the Harnai route, south-east of Harnai and on the road from Quat-Mandai to Thal Chotiali, the eocene beds exposed below the base of the Siwaliks are (the thicknesses being little more than guesses) :—

	Thickness at Spintangi.	Thickness at Tang.
a. Olive shales and sandstone	4,000 ?	1,000
b. Nummulitic limestone	800	1,000
c. Olive shales and sandstone	1,000	?
d. Nummulitic limestone (apparently of great thickness)	?	?

Throughout the Harnai route below Kach the lower nummulitic limestone *d* forms immense hills, including the Pil and Chappar ridges, the

[1] And, in part, in consequence of illness.

upper part at least of the huge mountain mass north of Sháhrág and Harnai, and a number of hog-backed elongate hills of smaller elevation. All these different ridges are anticlinal, except the Pil range, west and north-west of which the olive shales at the base of the eocene system are seen to underlie the lower limestone.

Correlation of thick limestone beds.

The question that presents itself is whether this massive limestone is the same as that of the Bolán Pass and Takátu, that is, whether the position in the system is identical in both cases. If it is, the overlying shales and limestone *a*, *b*, and *c* have been denuded to the west and south-west about Quetta and the Bolán. But if the limestone of the Pil range be the same as that of Zarghun, it should be distinctly seen to cross the valley below Kach; and although the outcrop may have been overlooked, I do not think it was. It is more probable that the massive limestone of Pil, Chappar, &c., is an expansion of the lower limestone seen intercalated in the shales near Gandak, north-east of Quetta, and that the great overlying limestone of Takátu and the Bolán route disappears and is replaced by shales and sandstones to the eastward.

Coal-bearing beds of Sháhrág.

The shales and sandstones, with occasional beds of limestone, that overlie the massive limestone *d* appear to be greatly developed about Sháhrág, where they occupy a valley about 10 miles broad. It is probable that they are folded so as to cause repetition of the same beds, otherwise the thickness exposed would be enormous, for the dip is generally high. Some beds of coal,[1] associated with occasional bands of impure fossiliferous limestone, intercalated in a series of soft sandstones, shales, and clays are found in this neighbourhood south and east of Sháhrág, and both the coal beds and their associated rocks precisely resemble the strata of Mach near Sir-i-Bolán on the Bolán route. The Mach seams do not appear to be much more than 1,000 feet above the base of the eocene system, while below the Sháhrág beds there are the shales, &c., of the Sháhrág plain, assuredly not less than 2,000 feet in

Relations to beds of Mach in Bolán Pass.

[1] A measured section of these and the associated strata will be found in Chapter VI.

thickness, and probably considerably more, together with the thick limestones of the range to the northward, and perhaps more shales below the limestone. Further examination of the country is necessary before the horizon of the Sháhrág coal seams can be determined with certainty, but sufficient is known to render it probable that these beds, despite their close resemblance to those of Mach, may be considerably later in age.

Eocene beds of Bugti hills.

The eocene strata of the Marí hills have not been examined, and in the Bugti hills, except to the eastward near the Punjab frontier, only the upper stages were observed. In the western part of the hills, near Lehri and Pulaji, the upper beds of the system consist of limestone with *Nummulites* and *Alveolinæ*, but there appears to be a gradual diminution of the limestone to the eastward. It should be mentioned that no denudation appears to have affected the uppermost beds before the deposition of the Siwaliks in the Bugti hills, and also in the Sulemán range further east, the latter strata being conformable and not resting on an apparently worn and denuded surface as in the Bolán Pass. South of Bugti Dera the uppermost beds are—

1. Shaly limestone containing small nummulites (*N. ramondi* ?) About 50 feet.
2. Pale olive shale, with reddish brown (coffee-coloured) bands. Several hundred feet.
3. Nummulitic limestone, more massive.

Sham plain.

To the north of Bugti Dera the limestone (No. 1) is much thicker than to the south. Further east, however, north of Gandahári (Gehandári) hill this bed disappears altogether. South and east of the Sham plain, and thence to the northward, along the flanks of the Sulemán range, the limestones are only represented by thin bands, each usually not more than 20 to 30 feet thick, and in many places it is very doubtful if 100 feet of limestone occurs altogether in the whole system from top to bottom, whilst one of the most persistent and conspicuous bands is formed by 2 or 3 beds of white gypsum, about 15 to 20 feet thick in the aggregate, that underlie the principal and most continuous of the limestone bands. This limestone band is a continuation of that forming the surface of Gandahári hill and is about 500 to 1,000 feet below the top of the eocene.

The Sham plain, like many other plains[1] to the northward and north-westward, is composed of soft shales and sandstones dipping at a low or moderate angle. The ranges that separate these plains from each other generally consist in part of the harder calcareous bands.

Eocene of Sulemán range.

The section of the eocene beds on the east flank of the Sulemán is approximately the following:—

	Feet.
(*a*) Shales, chiefly olive, with sandstones and a few thin beds of limestone	7,000 to 9,000
(*b*) Hard brown sandstones with a band of limestone breccia near the base	1,000

Brown sandstones.

These sandstones (*b*) are a new feature in the eocene system. They form a great part of the surface on the main range of the Sulemán. They are in general of rather coarse texture, compact, and very hard, usually ferruginous brown in colour, sometimes purplish, and often pale with dark red or brown spots. There is some resemblance between them and the sandstones beneath the *Cardita beaumonti* beds of the Laki range in Sind,[2] but the latter are much softer. In some places a band of limestone containing oysters was seen associated with the sandstones in the Sulemán range as in Sind.

Limestone breccia.

The limestone breccia of the Sulemán is precisely similar to that already described as occurring near Quetta and elsewhere, and as it is clearly interstratified with the sandstones at some distance above their base, it serves to mark the horizon and to show that in all probability not only are the brown sandstones eocene, but very low eocene, and the underlying white sandstones are probably to be referred to the cretaceous epoch as already stated.

Increase of limestone to northward.

The small quantity of limestone in the nummulitic system throughout the southern portion of the Sulemán range is remarkable. In the northernmost part of the

[1] These plains are much more extensive, and the intervening ranges less conspicuous and of smaller dimensions, than the hill shading on the map would lead any one to suppose.

[2] Mem. G.S.I., Vol. XVII, pp. 34, &c.

area examined, near the base of Saronk, the limestone in the eocene beds appears to increase again, and in the Soundhra or Sangarh stream a band between 200 and 300 feet thick is cut through. This band is in the middle of the system, having a great thickness of shales both above and below; it continues to the northward, and forms a well-marked ridge known as the white range.

West of Sulemán.

To the west of the Sulemán also, as was clearly shown by Mr. Ball,[1] the limestone is much better developed than to the eastward. A thick bed of limestone, measuring approximately 700 feet, is seen capping the sandstones and shales. But it by no means follows that the limestone was originally the uppermost member of the eocene system; more probably here, as in so many other places, and especially east of the Sulemán, the highest beds were shales and sandstones, overlying the principal calcareous band, but the soft overlying strata have been removed by denudation. The coal-bed of Chamarlung is shown by Mr. Ball to be just beneath the limestone, and consequently rather high in the system, probably above rather than below the middle. A great thickness of shales, sandstones, &c., probably 5,000 to 6,000 feet, must underlie the coal horizon, which may perhaps be the same as that of Shahrág on the Harnai route, but is more probably later, and which certainly appears to be considerably higher in the system than that of the Mach or Sir-i-Bolán coal. So far as the evidence extends, it is rather in favour of very similar beds recurring in various localities at different horizons.

Coal of Chamarlung.

Eocene of Northern Punjab.

Northward of the area visited on the flanks of the Sulemán range there is a break of nearly 100 miles before reaching the limits of Mr. Wynne's work near Shekh Budín. In the hill ranges extending thence along the western side of the Indus, the eocene system is poorly seen, as at Shekh Budín itself, where the system is represented to consist of limestone below, with shales clays and sandstones above;

Shekh Budín.

[1] Rec. G.S.I., Vol. VII, p. 151.

and it appears to be entirely absent in places. Finally, in the Salt-range east of the Indus, the section[1] consists of

Salt Range.	(*a*) Pale limestone . . .	400 to 600
	(*b*) White sandstones, shales, and red and grey clays with lignite and gypsum . .	150 to 300
	(*c*) Olive, reddish and white sandstones.	150 to 200

The latter have hitherto been considered probably cretaceous and perhaps with reason, but it is on the whole quite as probable that their upper members may be eocene, like the other olive beds. The boulder bed at the base of the group may, however, very possibly be older.

Hazára and Murree.

North of this, in Hazára, the eocene system is chiefly composed of thick dark-coloured limestone, whilst the calcareous element again diminishes in quantity near Murree and the Jhelum valley. In the same beds of the Upper Indus valley, Ladák, much further to the northward, scarcely any limestone occurs, and the strata, although contorted and indurated, appear to be not dissimilar in character to the shales and sandstones of the hills on the south-west Punjab frontier. Near Simla, much further east, the Subáthu nummulitic beds agree in character, to judge from the description, with the soft olive brown and red shales, clays, and sandstones of the Sulemán range.

Ladak.

Subáthu near Simla.

3. Nari. (*a*) *Lower Nari or Oligocene.*—The lower Nari or oligocene limestone, so well and constantly developed in all parts of Western Sind,[2] except the south, was only detected at one place to the northward. This was in the hills immediately north of Bibi Náni (2 or 3 miles north-west of the military post bearing that name) near the Bolán route. At this place the typical brownish limestone (orange brown to wood brown) occurs resting, to all appearance conformably, on whitish or grey eocene limestone, the

Lower Nari beds.

[1] Mem. G. S. I., Vol. XIV, p. 69. Manual of the Geology of India, p. 481.
[2] Mem. G. S. I., Vol. XVII, pp. 49, &c.

Nari limestone containing the typical *Nummulites sublævigata, N. garansensis*, and *Orbitoides papyracea*. There was no opportunity for examining the spot carefully, and it is doubtful whether any of the higher Nari beds are found, although some variegated strata, seen on a neighbouring hill, may represent a portion of them.

Not a trace of the oligocene limestone was detected east or north of the locality named, and it appears now somewhat doubtful whether the oligocene sea extended further to the northward.[1]

Upper Nari beds.

3. (*b*) *Upper Nari.*—No rocks representing the Upper Nari beds of Sind were seen on the Bolán or Harnai routes, nor throughout the Bugti hills, as far east as the neighbourhood of Gandahári hill, some 20 miles east of Dera Bugti. North of this hill, however, a remarkable series of sandstones, with subordinate beds of conglomerate and clay, 700 feet or more in thickness, is seen resting upon the eocene shales and limestones with perfect conformity. The most conspicuous beds of the overlying formation are earthy brown (greyish brown) sandstones of great thickness, rather darker and harder than the Siwalik sandstones,[2] and with these brown sandstones are

[1] In this case, the statement I made in the Manual of the Geology of India, page 504, that there is very little doubt that the Nari group is represented in the Punjab, because some of the characteristic species of nummulites have been brought from Punjab localities, must have been founded on a mistake. I certainly, on one occasion, saw specimens which I identified with *N. garansensis*, and I think *N. sublævigata* also, in the Geological Survey Museum at Calcutta, and these specimens were said to have been brought from the Northern Punjab, I think from the neighbourhood of Murree, but I have not been able to re-discover them, and there may have been some error in the locality or identification.

[2] Whilst engaged in correcting the proofs of this memoir for the press, I have received Mr. Lydekker's "Geology of the Káshmir and Chamba territories; Mem. G. S. I., Vol. XXII. In this the tertiary rocks of the Pir Panjál are divided (p. 47), in descending order, into Outer Siwaliks, Inner Siwaliks, Murree group and Subáthu group. So far as the number of groups is concerned, this coincides with the classification of the Sulemán tertiaries adopted in the present memoir, *viz.*, Upper Siwalik, Lower Siwalik, Nari beds, and Eocene. But the most important point is that the description of the Murree sandstones (p. 88) agrees singularly well with that of the Nari sandstones. Both have a considerable resemblance to those of the Siwaliks, but are distinguished by being harder and darker. The limits of the Murree beds have hitherto been somewhat indefinite, owing to the difficulty of distinguishing higher and lower strata of somewhat similar character, but if the harder and darker sandstones above the Eocene can be recognised as a distinct group, both on the Pir Panjál, east of the Jhelum, and on the Sulemán, west of the Indus, there appears good reason for believing that the same group of beds may be traced without difficulty across the Punjab.

associated, especially towards the base, dark reddish-brown sandstones, and reddish and yellowish-brown clays, some bands stained red by iron, and others black, apparently by manganese. One argillaceous sandy bed of a dark green tint mottled with red has a singular superficial resemblance to a volcanic rock.

Precisely similar beds occur throughout the hills to the east of the Sulemán, underlying the Siwaliks (or Manchhar), and resting upon eocene strata. There can be very little doubt that these beds are identical with the Upper Nari in Sind, although, in the Sulemán range, neither the oligocene limestone is to be seen at the base, nor the marine Gáj beds overlying. Despite the absence of these two important stages, no unconformity whatever, though carefully searched for, could be detected between the Nari beds and the strata above and below them.

Absence of marine miocene beds.

The complete absence of any representatives of the Gáj,[1] the great miocene group of Sind, throughout the area examined, is a great drawback in endeavouring to trace the distinctions of the different stages above the eocene system. Still no difficulty has been found in distinguishing, throughout the eastern flank of the Sulemán range, as far north as the survey was carried, three groups, composed chiefly of sandstone or conglomerate, conformable to each other and very rarely and exceptionally fossiliferous. These groups are the upper Nari just described and the upper and lower Manchhars or Siwaliks.

Lower Siwaliks.

4. *Siwalik or Manchhar.*—The rocks to which, in order to avoid any risk of introducing confusion into the terminology, the name of Manchhar was given in Sind, may, now that they have been traced so far to the northward, be identified without hesitation as Siwalik, and the latter name, which is older and far better known, may be

Identity of Siwaliks and Manchhars.

The separation of this group would go far towards completing the classification of the Punjab tertiaries, for the age of the Nari beds is well established by their position between two marine groups in Sind.

[1] Unless, as is possible, the lowest Siwalik beds, those containing vertebrate bones and the fresh-water mollusca subsequently noticed, represent the Gáj of Sind.

used for them. It must, however, be borne in mind that the mammalian and reptilian fossils found in Sind and the neighbouring countries came from the bottom of the system, whilst those of the Jumna and the base of the Himalayas generally are from near the top, and that the former belong to a far older fauna than the latter, the former being probably miocene, the latter pliocene.

Lower Siwalik of Bugti and Sulemán hills.

4 (*a*) *Lower Siwalik.*—The Lower Siwaliks of the Bugti hills and Sulemán range consist principally of the characteristic grey sandstone, a soft rock, moderately fine-grained, and owing its grey colour to small grains of a black mineral (probably hornblende) interspersed amongst the whitish quartz (or quartz and felspar) grains. With this grey sandstone are interstratified numerous bands of a peculiar conglomeratic rock, consisting of nodules or fragments of clay and soft sandstone, usually rolled, imbedded in an argillaceous or occasionally a sandy matrix. No pebbles of harder rocks occur. All the fragments appear to be derived from formations precisely similar in colour and mineral character to those associated with the conglomeratic or pseudo-conglomeratic beds themselves. Beds of clay often occur in this subdivision, and they are not unfrequently of a red (usually Indian red) colour; occasionally they are broken up, and the separate portions, sometimes a foot or two in diameter, rolled and re-deposited in a matrix of sand or clay of a different colour. Highly ferruginous bands, not uncommonly consisting of pseudo-conglomeratic beds strongly impregnated with iron, are found near the base of the group, and richly coloured clays and sands of varying tints are often seen in the same position.

Mammalian and reptilian remains.

In the lower beds of this subdivision fragments of mammalian and reptilian bones occur locally in considerable numbers. It is rare for the bones to be perfect, but still occasionally unbroken specimens are found, and in one instance the greater portion, if not the whole, of a *Rhinoceros* skeleton, appears to have been imbedded. Several forms have been determined by Mr. Lydekker from beds in the same relative position in Sind, and from others supposed to

belong to this horizon in the north-western Punjab. It has already been mentioned in the introductory chapter that bones were noticed in these rocks near Dera Bugti by Captain Vicary, and several localities, especially Gandoi, Kumbi, and a spot 5 or 6 miles south-east of Dera, are prolific in remains of *Vertebrata* and also of mollusca. Of the former, *Mastodon* and *Rhinoceros* are the mammalia most frequently represented. Some teeth of *Dinotherium* have been obtained, and molars of an *Anthracotherium* and of a huge *Hyopotamus*.[1] Several teeth and bones await further examination. Bones of crocodiles, garials, and tortoises of various kinds are also found in considerable quantities. But the most important discovery was that of the following seven or eight species of fresh-water shells. They are described and figured in the appendix to this report.

Melania pseudepiscopalis, sp. nov.
M. gradata, sp. nov. 2 vars.
Paludina bugtica, sp. nov.
Unio vicaryi, sp. nov.
U. cardiiformis,[2] sp. nov., 2 vars.
U. cardita, sp. nov.
U. pugiunculus, sp. nov.

As will be seen by the above list, all of the seven species, sufficiently well preserved to be compared, are extinct and hitherto undescribed; one, however, *Melania pseudepiscopalis*, is closely allied to several living forms, and another, *Unio pugiunculus*, is less nearly related to some existing species. In both cases the surviving representatives are found in countries at a distance to the eastward. *Paludina bugtica* is not a characteristic type, but it is not near any living Indian form of the genus. All the other species are very different from anything now known to exist in any part of the globe.

[1] Since the above was written, some of these have been described by Mr. Lydekker (Pal. Ind. Ser. X, Vol. 2, Pt. 5, pp. 152, 158, &c.) as *Anthracotherium hyopotamoides* and *Hyopotamus giganteus*. The *Mastodon* found has been identified with the European *M. angustidens* (Rec. G. S. I., Vol. XVI, p. 161). The *Rhinoceros*, I learn from Mr. Lydekker, may perhaps be new, but it requires further comparison.

[2] It is probable that the ill-preserved ribbed bivalve mollusca found by Mr. Wynne in the beds overlying the eocene of Kohát, Mem. G. S. I., Vol. XI, p. 168, may have been of the Unios now described.

All the above are typically fresh-water, probably river,[1] forms. They are associated with bones and teeth of rhinoceros. In the Sulemán hills, at the same horizon, close to the base of the Siwalik system, a few ill-preserved remains of mollusca were found in two localities. The majority appear to be fresh-water shells, and they comprise two forms of *Unio* closely resembling those obtained from the Bugti hills and probably identical, but with these Unios at one locality were a *Cerithium*, a *Natica* and a *Cyrena*-like shell, showing the presence of salt water. The bed in this case may have been of estuarine origin.

Relations to Upper Siwalik forms.

When it is remembered how close is the connexion between the Upper Siwalik mollusca of the Sub-Himalayan tract and those now living in the country,[2] and that, out of a considerable number of species found in Upper Siwalik strata, only one is supposed to be extinct or wanting in the recent fauna of Northern India, the circumstance that all or nearly all the forms from the Lower Siwaliks are extinct, and that none are even allied to the species of the same genera now inhabiting the country where they are found fossil, shows how wide a difference in age there must be between the two faunas, and renders it probable that a long period of time elapsed between the formation of the deposits in which they severally occur. The mammalian remains, as has already been shown,[3] led to the same conclusion, which is supported by the additional mammalian discoveries recently made.

Geographical distribution of Lower Siwaliks.

In the country recently examined, the Lower Siwaliks are found throughout the Sulemán range as far north as the survey extended, and throughout the southern

[1] All the Unios have thick heavy shells. This would prove but little alone, but the absence of any species with thin shells is opposed to the probability of the fauna having inhabited a marsh or lake. The absence of *Lymnæa*, *Physa*, *Planorbis*, and other lake and marsh-loving forms tends to the same conclusion. At the same time, the circumstance that in most of the specimens of *Unio* both valves occur united shows that the shells must have been preserved almost on the spot where they lived, and that they have not been washed any distance down a river.

[2] Manual of the Geology of India, p. 576, and Rec. G. S. I., Vol. XV, 1882, p. 106.

[3] Manual, pp. 472, 581, &c.

part of the Bugti hills. To the westward, however, the lower subdivision of the Siwalik system appears to die out, and although it may be represented on the west flank of the Bugti hills near Lehri, it entirely disappears further to the northward, for both on the Nári river and on the Bolán, Upper Siwalik beds rest directly, and in the latter case, unconformably, upon the eocene. The Lower Siwaliks appear always, in the Sulemán and Bugti hills, to be conformable to the rocks underlying them, whether these rocks belong to the Upper Nari group, as in the Sulemán range, or to the eocene, as in the Bugti hills. The perfect conformity in the latter case is very remarkable, for, at a distance of a few miles to the north-east, a mass of Nari sandstones and clays, little if at all less than a thousand feet in thickness, is intercalated, whilst at no great distance to the south-west, in Sind, several thousand feet of Gáj and Nari beds intervene. The sections in the Bugti hills are admirably adapted for exposing unconformity, if any exists; the boundary can be traced without a break, for 20 or 30 miles or even more, along barren cliffs and steep hill sides; and the Siwaliks, throughout this distance, rest upon a thin band of shaly limestone, underlain by soft shales and clays. The removal of the limestone at any place before the deposition of the Siwaliks would be easily detected, more especially as the soft underlying beds would in all probability have suffered from erosion. To complete the singularity of the case it must be remembered that not only is there a huge geological break between the two systems, a break represented by two whole groups of an aggregate thickness of 5,000 to 7,000 feet in a neighbouring country, but the lower or eocene system is purely marine, whilst the overlying Siwalik beds are entirely fresh-water or subaërial.

Relations to underlying beds.

4 (b) Upper Siwalik.—The Upper Siwaliks have a far more general distribution than any of the other tertiary groups above the eocene. They are perfectly conformable to the Lower Siwaliks, and indeed pass into them, yet the two are easily distinguished, as a rule, by the circumstance that the pseudo-conglomeratic beds, above described as consisting of clay or soft sandstone

Upper Siwalik.

nodules or fragments in an argillaceous or sandy matrix, are characteristic of the inferior sub-division, and are replaced in the upper group by true conglomerates of hard sandstone and limestone pebbles, in a sandy or calcareous matrix. Nummulitic limestone pebbles abound in the Upper Siwaliks of Baluchistan and the South-Western Punjab, but are not found in the lower, and the sandstones prevailing in the former are light-brown in colour, not grey as in the latter.[1] The sandstones of the Upper Siwalik do not differ greatly from those characteristic of the upper Nari beds, but the former are softer, paler in colour, and less earthy or greyish-brown.

Towards the top, as in Sind and elsewhere, the Upper Siwaliks become very conglomeratic, and the uppermost bed is usually an excessively coarse and massive conglomerate, generally abounding in rolled pebbles of nummulitic limestone. This conglomerate is frequently conspicuous from its forming a range of hills, sometimes of considerable height, at the verge of the hill area and on the edge of the alluvium. In one place near Choti Bálá, south of Sakhi Sarwar and south-west of Dera Gházi Khán, there is distinct unconformity between this uppermost conglomerate and the other beds of the Upper Siwaliks, but the unconformity is probably local and exceptional. As a rule, absolute conformity and transition prevail between all the subdivisions of the Siwalik system. At the same time, as has already been noticed, the Upper Siwalik beds overlap both the Lower Siwaliks and the Nari group, and rest upon the eocene beds in the hills surrounding the Kachi, and in the Bolán Pass there is great unconformity between the Siwalik and eocene beds, the bed resting upon the nummulitic limestone near Kohandiláni being apparently the uppermost Siwalik conglomerate.

Distribution on margin of Indus plain.

The Upper Siwaliks appear to form an unbroken fringe to the Indus alluvium from the south-western extremity of the area examined near Sibi to the neighbourhood of Dera Gházi Khán. Further north than the last named station, in some places at all events, the beds bordering the alluvial plain are apparently

[1] This distinction does not, I believe, hold good in the Sub-Himalayan tracts.

Lower Siwalik. The Upper Siwalik beds are, however, not confined to the margin of the hills, they occur in a long synclinal belt near the base of the Sulemán range north of Sakhi Sarwar, and similarly near Bugti Dera. They may perhaps also be found in the Mari hills. A conglomerate so closely resembling the uppermost Siwalik conglomerate as to be undistinguishable from it occurs around the Laláchi and Kirta plains on the Bolán route, and is also found, generally much disturbed and turned on end, in the valleys between Quetta and Kach on the Harnai route.[1] It should also be mentioned that Mr. Ball[2] observed similar conglomerate to the west of the Sulemán range. The circumstance that the Siwalik beds seen resting unconformably on nummulitic limestone in the Lower Bolán Pass, near Kohandiláni, are conglomerates of precisely similar character, tends to confirm the idea that the inclined conglomeratic beds around the Kirta and Laláchi plains and elsewhere in the neighbourhood belong to the same division of the Siwaliks.

Siwaliks near Quetta.

The occurrence of Siwalik conglomerate north-east of Quetta, on the road to Kach, has just been mentioned. West and north of Quetta other beds, chiefly clays and sandstones, that have every appearance of belonging to the Upper Siwaliks, recur in great thickness. They form the greater part of the Mashalak range, traversed by the Gháziaband Pass, and they appear to be extensively developed in Pishin. These beds have already been noticed in the introductory chapter, where reasons have been given for assigning them to the Upper Siwaliks, instead of to the Gáj, as supposed by Mr. Griesbach.

Fresh-water origin of Siwalik system.

It is scarcely necessary to recall the fact that nearly the whole Siwalik system on the north-eastern, northern, and western margins of the Indo-Gangetic plain consist of fresh-water or subaërial deposits. The few exceptions known

[1] I am informed that similar conglomerate occurs on Zarghun hill, over 11,000 feet high north-east of Quetta.

[2] Rec. G. S. I., Vol. 1874, VII, p. 150.

are local, and consist of beds, probably estuarine, at or near the base of the series, and at no excessive distance from the present coast, the most remote locality being the South-Western Punjab. By far the greater portion of the strata appear to have been deposited by rivers. The conglomerates of the Upper Siwaliks are evidently due to stream action, and the clays and sands, together with the conglomeratic beds or agglomerates containing pellets of clay and soft sandstone, have all the appearance of river deposits. Indeed many of the beds are very similar in character to those forming the great Indo-Gangetic plain; the gravels of the *bhábar* corresponding to the Siwalik conglomerates. It is true that the pebbles in the recent gravel slopes west of the Indus are more frequently subangular and less generally rounded than those of the Siwaliks, but in the tract at the base of the Himalayas, where the rainfall is so much heavier, the rounding of the pebbles is much more complete.[1]

Former extension of Indo-Gangetic plain.

The occurrence of the Siwaliks within the outer Afghan and Baluch hills at a considerable elevation above the sea may probably indicate that the great river plain of Northern India extended further to the westward and north-westward in Siwalik times than it now does, whilst the absolute conformity of Siwalik to eocene strata in so many places shows that in those places, at all events, the nummulitic rocks had been neither up-heaved nor disturbed till after the deposition of the Siwalik system. In other parts, however, as in the Bolán, the eocene beds had been disturbed, at all events before the formation of the Upper Siwaliks. The general evidence, nevertheless, on the margin of the South-Western Punjab, as in Sind, is that the disturbance of all the beds from the cretaceous upwards is mainly post-pliocene. In this respect there would appear to be a difference from the conditions described by Mr. Medlicott[2] as existing in the Sub-Himalayan tract, and this difference may indicate that the dis-

[1] This at least is the case so far as my observation has extended, but it would be well if some additional attention were devoted to the subject.

[2] Manual of the Geology of India, p. 570, &c.

turbance of the Himalayas preceded that of the north and south ranges west of the Indus.[1]

Post-pliocene and recent beds.

Post-pliocene and Recent.—If all the disturbed beds of conglomerate on the Bolán and Harnai routes and around Quetta be referred, as just suggested, to the Siwalik system, only the deposits of the various plains within the hills, and the slopes of gravel along the foot of each range, will remain to be considered as of post-pliocene age, together with the Indus valley alluvium.

Indus alluvium.

All these formations or deposits corresponding to them have been fully described and discussed already.[2] The plain of the Indus is covered by deposits from the flood waters of the river, mixed with fine dust and sand transported by the wind. In many places large tracts are covered with hillocks of blown sand, the abundance of this form of surface being always in approximately inverse proportion to the rainfall, for heavy rain tends to carry all such loose formations into the streams and thence to the sea. Along the edge of the hills is a slope of rounded or subangular gravel derived from the ranges. Where streams issue from the hill country, the gravels of the slope are more developed than elsewhere, and form the well known fan-shaped deposits. Generally to the west of the Indus the slope extends for a mile or two from theout ermost ranges; occasionally, however, the breadth is greater. Far beyond the marginal slope, the surface deposits are mainly composed of finer detritus brought down by the hill streams and spread by them far and wide over the surface of the plain. The "pat" or desert of the Sind frontier is mostly covered with silt derived from the hill ranges.

Gravel slope or Bhábar.

[1] In Sind also the principal disturbance appears to have been post-pliocene; Manual of the Geology of India, p. 474.

[2] Manual of the Geology of India, pp. 391, 421, 473, &c. Q. J. G. S., 1873, p. 496. Eastern Persia, Vol. II, p. 465. See also Drew, Q. J. G. S., 1873, p. 445, v. Richtofen, China, I. pp. 56, &c. Tietze Jahrb. k.k. Geol. Reichsanst. 1877, p. 341, 1878, p. 581. Griesbach. Mem. G. S., Vol. I. XVIII, p. 9, &c.

The great gravel deposit of the Khirthar and Sulemán ranges not only forms a slope along the margin of the plain country, but it frequently occupies large areas within the outer ranges. In these instances an opportunity is afforded of seeing the process by which the great gravel slopes that fringe the plains of Central Asia have been formed, before the minor ridges have been covered up by the detritus derived from the higher.

The pebbles composing the gravel of these deposits are partly subangular, partly rolled. It is not always clear why some pebbles apparently derived from the same rock are much more rolled than others. The difference does not depend upon size. Some large boulders are rounded and some small fragments angular.

Post pliocene beds of hills.

On the plains within the hills the surface formations vary greatly. Sometimes, as on the Sham plain, the thickness of these accumulations is inconsiderable, and the underlying beds are exposed over a large portion of the area. Elsewhere, as near Quetta, the whole surface of the plain consists of subrecent deposits of great thickness, partly of aqueous origin, and washed by streams or floods from the hills around, partly in all probability, as in the Indus valley, derived from the atmosphere and consisting of fine particles transported by the wind. The latter form prevails towards the middle of the plains, whilst along the margins coarser detritus is deposited from water, so as to form the slopes of rounded and subangular gravel noticed by so many travellers, not merely in Afghanistan, but throughout the greater part of Central Asia. In the gravels of the slopes the underground channels known by the name of *Karez* in Afghanistan (and I believe throughout the Turk or Turcoman countries), and by the term *Kandt*, in Persia, are dug for the purposes of obtaining water for irrigation.

PART II.—DETAILS.

CHAPTER IV.

NOTES ON THE ROUTE FROM SIBI TO QUETTA BY THE BOLAN PASS.[1]

Alluvial plain near Sibi.

The greater part of the alluvial plain near Sibi resembles the "pat" or Sind desert which is near the base of the hills and owes its formation to deposits from the hill streams. There are, however, near Sibi, a few hillocks covered with pebbles, chiefly of nummulitic limestone. One or two similar hillocks

Hillocks of Siwalik.

covered with pebbles occur about 8 miles further south, near Pirak Pir (the tomb of a *pir*, or Mussulman saint, on one of the rises), and others towards Bráhim Barán, south-west of the road from Sibi to Pir Choki at the entrance of the Bolán Pass. The pebbles may be derived from a post-pliocene conglomerate, but as, beneath similar pebbles, both to the south-west near Dádar and south-east near Mal, Siwaliks appear, there can be very little doubt that the sandy clay of all these small hillocks is decomposed Siwalik sandstone and other beds, and the pebbles may be derived from Siwalik conglomerates.

South-east of Dádar and Pir Choki these hillocks rise into low hills,

Hills between Dádar and Mittri.

and form a tract of broken country extending for many miles from north-east to south-west. The low hills are crossed on the road between Mittri and Dádar, and have been noticed by many observers, from Hutton to Griesbach. They have especially been mentioned in the preceding introductory chapter, on account of the rocks composing them having been referred by the last named writer to the Gáj group. I crossed these hills from Pir Choki

[1] Many of these notes on the Bolán Pass are identical with those published by other observers, but they are here given as a whole to prevent the necessity for searching through numerous works for a description of the geology. Many of the observations, too, are, if not new, at least connected with a classification of the geological formations differing somewhat from that adopted in other descriptions of the route.

to near Mittri. They are composed of light brown or drab sandstones and clays with a few beds of gravel or soft conglomerate. A little gypsum occurs in flakes. I saw no red or white clays.[1] The hills are formed by a low anticlinal, and the beds dip west-north-west near Dádar and east-south-east on the Mittri side. The dip rarely exceeds 5°, and not more than 1,000 feet of beds can be exposed on the road traversed.

The beds are Upper Siwalik.

The beds are clearly, so far as I can judge, Manchhar or Siwalik, and I think all seen by me must be classed in the Upper Siwalik subdivision, as already stated in the introductory chapter. No Lower Siwaliks were detected in the neighbourhood, and no characteristic Lower Siwalik rocks, such as the grey sandstone, or the conglomerate of clay nodules, were found amongst the beds of the Dádar hills.

Relations of Siwaliks in Dádar hills to those of Pir Choki.

Dádar is on the alluvial plain that intervenes between the hills just noticed to the south-east and the outer ridges of the main range to the north-west. The Bolán Pass leading into the latter is entered at Pir Choki. Here the beds are Upper Siwaliks dipping north-west, and if the same dip is continuous beneath the alluvium around Dádar, the strata composing the hills to the south-east of Dádar must be at a considerably lower horizon. But, a few miles north of Pir Choki, the Siwaliks at the edge of the main range are seen to dip south-east, and there is much probability that they do the same beneath the alluvial plain between Pir Choki and Dádar, in which case the beds of the Dadár hills may be merely a repetition of those to the westward.

Siwaliks of Pir Choki.

The Siwaliks seen at Pir Choki consist of drab clays and sandstones, with some bands of conglomerate. All appear to be Upper Siwalik. The dip is about 10° to 15° to west-north-west. For about 3 miles the road, following the Bolán river, has a north-west direction, then there is a sharp turn to

[1] Some were noticed by Griesbach on the road he traversed, which lies 4 miles north of that examined by me. The beds seen on the two roads must be nearly on the same horizon.

the south-west. Just at the bend in the river, coarse conglomerate comes in, resting upon the sandstones and clays, and continues for about 6 miles to Kohandiláni, the road throughout running nearly parallel to the strike of the beds, which, however, dip rather irregularly. At Kohandiláni there is another abrupt change in the direction of the stream, and the road turns due north. The conglomerate continues for about half a mile, and then nummulitic limestone crops out from beneath it, apparently quite unconformably. The conglomerate is massive, neither sandstone nor clay being interstratified in general; it contains large pebbles of nummulitic limestone in abundance, and it has every appearance of being the uppermost conglomerate of the Siwalik system.

Conglomerate.

From half a mile above Kohandiláni the road traverses a narrow gorge in the nummulitic limestone till near South Kirta. The limestone at first is very nodular,[1] subsequently more distinctly bedded. The dip is irregular, but lower bed gradually appear, and before reaching South Kirta, sandy clays, light brown and olive grey in colour, crop out from beneath the limestone. These clays, as Mr. Griesbach has shown, are doubtless representatives of the beds at Mach, higher up on the Bolán route.

Nummulities of Lower Bolán.

At South Kirta the gorge, through which the route has passed from Kohandiláni, terminates, and the road enters upon a large plain, covered with coarse gravel. This plain, called Laláchi to the north and Kirta to the south, on the map, extends about 25 miles from north to south, and is, where broadest, 6 miles wide. The gravel appears to have been entirely deposited by streams running from the surrounding hills, and is rather coarse in general, many of the fragments composing it being subangular, and a very large proportion of them consisting of nummulitic limestone. The surface of the plain is not absolutely level; there is a considerable ascent from south to north, and large fan-shaped deposits of coarse pebbles

Plain of Kirta and Laláchi.

[1] Griesbach, p. 80, suggests the possibility of this limestone being Nari. This, however, is not the case. Similar beds are not uncommon in the Khirthar of Sind.

occur at points where streams issue from the hills. One of the best marked of these is at Bibi Náni, the halting place beyond South Kirta. From the camp at Bibi Náni the road, instead of ascending as usual, descends over a distinct slope for some distance till the edge of the fan is reached, thence there is again an ascent. But no stream bed occurs at the bottom of the depression; the water of the stream to which the fan is due runs nearly at the top of the incline and supplies the Bibi Náni camp with water.

Fan deposit at Bibi Náni.

The hills around the plain are chiefly composed of nummulitic limestone, but at their base, throughout a great portion of the circumference, are low hills or hillocks of conglomerate, evidently of greater antiquity than the gravels of the plain, for the beds are inclined instead of being horizontal. Close to South Kirta, about 200 or 300 yards south of the camp, some small hills of this conglomerate consist of beds dipping 25° or 30° to the westward. The conglomerate is darker in colour than the gravels of the plain, in consequence of the large proportion of dark grey limestone pebbles, perhaps derived from cretaceous beds, that it contains. All the pebbles are thoroughly rounded, and some of them are of large size, some pieces of the dark grey limestone being a foot in diameter. Altogether the resemblance of this conglomerate to that of Siwalik age seen resting unconformably on nummulitic limestone near Kohandiláni is so great that the two are probably identical. As will be shown hereafter a similar conglomerate is very conspicuous on the Harnai route north-east of Quetta.

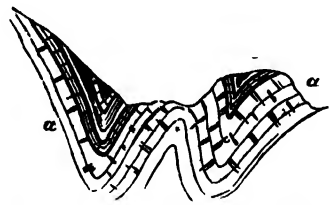
Siwalik conglomerate around plain

On the hills north-west of the camp of Bibi Náni (the range north of the spot called Bibi Náni on the map), a brown rock rests upon the nummulitic limestone, and, on account of the colour, is conspicuous from a distance. This brown rock proves, on examination, as already mentioned in the introductory chapter, to be the typical oligocene limestone of the Nari group,[1] precisely the same

Nari oligocene limestone near Bibi Náni.

[1] I am not at all surprised at Griesbach's not having noticed this bed. My own recognition of it was partly accidental; had I been marching from the north instead of from the

as in Sind, and abounding in the characteristic *Foraminifera; Nummulites paranensis, N. sublævigata,* and *Orbitoides papyraceus.* On the eastern side of the range, seen from the road, the Nari beds only appear in patches, and near the crest of the hills; but they line a small valley running nearly north and south between two parallel ranges, the more eastern of which is on the border of the plain. Besides the brown limestone, on the west of the small valley, there are some highly coloured variegated beds, purple, red, and white, probably also belonging to the Nari group. The brown Nari limestone is vertical, and has the appearance of being let in by synclinal folds, as in the following figure:—



Sketch section near Bibi Nání; *a* Eocene, *b* Oligocene.

Hills near Ab-i-gúm.

The ridge of hills on which Nari beds are exposed continues to Ab-i-gúm.[1] North of this place is a range of hills that looks from the road like a continuation of that to the south, and on this northern range there are also conspicuous brown limestones, but, on examination, where the hills approach the road, these beds appear to be below instead of above the main mass of nummulitic limestone, and to contain none of the characteristic oligocene foraminifera. Either there must be a fault at Ab-i-gúm, or the beds are much twisted and contorted.

The road leaves the open plain and enters more broken ground, shortly

south, I should probably have supposed it to be the same as a brown limestone seen, a little further north, much nearer to the road, and of lower eocene age. Of course when traversing a country rapidly, rocks at a distance from the road are only visited when there is reason to suppose they present features of peculiar interest.

[1] Ab-i-gaum of the accompanying map.

before arriving at the post known as Mach,[1] a locality that has attracted notice on account of the occurrence of coal or lignite beds in the immediate neighbourhood.[2] The rocks near the camp at Mach are all lower in position than the main mass of nummulitic limestone, which comes in to the eastward, and which they underlie; they consist of grey and olive shales, weathering into clays at the surface, soft sandstones, thin bands of coal,[3] and a few calcareous beds containing marine, or perhaps estuarine, fossils in great abundance, but of few species. One of the coal beds,[4] opposite the camp at Mach, measures 30 inches in thickness at one spot, but it is extremely doubtful if the thickness is constant for more than a few yards. The seam dips at 30° to the northward, and several smaller seams occur above it at intervals of a few feet. The thinness of the seams, the high

Beds associated with coal near Mach.

[1] Close to the spot marked Bent on the map. The place marked C. G. (? camping ground) is probably that called Ab-i-gúm by some travellers, and lies a little north-east of Mach.

[2] For a description of the coal and of its value for economic purposes see Rec. G. S. I., 1882, Vol. XV, p. 149.

[3] Griesbach's section, *l. c.*, pages 24-26, gives a fair idea of these beds. He states that the coal is formed of seaweeds, but does not give his reasons for adopting this opinion. I did not observe any remains of plants sufficiently well preserved to afford a clue to the character of the vegetation now preserved as coal.

I may here remark that I am not disposed to agree with Griesbach's view, that the lateral movement or pressure to which the convolution of the Mach beds is due "must have acted from the south-east towards north-west." I am rather disposed to believe that the pressure came from the westward or north-westward. To the south-east in the Bugti hills, and still more towards Sukkur and Rohri in Sind, the rocks are but little disturbed, whilst in the opposite direction the disturbance is excessive, showing, I think, that the lateral movement was greatest in that direction. Moreover, all round the Indian Peninsula, the thrust has the appearance of being towards the peninsula, not away from it. See Manual of the Geology of India, Introduction, p. lviii; Suess, Entstehung der Alpen, pages 126-144. Another point too on which I feel some doubt is whether, as Griesbach thinks, "the clays may have been pushed over the harder underlying limestone." It is more probable, I would suggest, that the actual lateral movement has been the same in both, although the effects may be somewhat different in producing contortion.

[4] An analysis of this coal by Mr. F. R. Mallet, gave—

Water driven off at 230° Fahr.	10·9
Volatile matter exclusive of water	33·1
Fixed carbon	41·0
Ash	15·0
	100·0

dips, and the softness of the associated beds combine to render any attempt to work the coal on a large scale hopeless. A considerable quantity of useful fuel can doubtless be obtained, but no permanent supply for large works, unless thicker beds are found under more favourable conditions.

The best sections are seen in the tributary streams, especially in one that joins the main stream or Bolán just opposite the camp of Mach. This tributary is the Maki nadi of the quarter inch map.

Conglomerate near Mach.

In the main stream itself scarcely anything is seen except conglomerate, disturbed in places, for instance just above the camp, on the west bank of the stream, where the dip is 30° to the westward. There is, however, much difference between this conglomerate and that occurring along the edge of the plain to the southward and supposed to be of Siwalik age, for the pebbles in the Mach conglomerate are less rounded, and boulders occur, some of them 5 or 6 feet in diameter.

Road north-west of Mach.

Beyond Mach, as far as Sir-i-Bolán, a distance of about 6 miles, the road runs in a north-west direction near the river, over a plain of gravel that extends for some distance to the east and north-east. South-west of the river, at a little distance, is a range of hills, composed of rocks, chiefly limestone, underlying the beds of Mach, and apparently of cretaceous age. The olive

Basement beds of eocene

and grey shales and their associates are seen at intervals in the main stream and to the westward for some distance, being in general nearly or quite vertical. At the base of the range to the westward, at the only spot examined, in a position intermediate between the eocene shales and the limestones of the hills, a bed of limestone breccia was seen, of the peculiar character noticed in Chapter III as characteristic of the basement beds of the eocene system, and consisting of dark angular limestone fragments in a rather paler grey limestone matrix, both matrix and included fragments containing *Nummulites*. A ferruginous brown band abounding in small *Nummulites* was also seen.

A good section of the rocks beneath the eocene, the same doubtless

as those forming the range first noticed, is exposed in the narrow stream bed of the Upper Bolán Pass, through which the road runs from Sir-i-Bolán to Dozán. One of the highest beds seen is a dark grey limestone abounding in small *Nummulites* and *Operculinæ*, and with peculiar forms, probably concretionary, but resembling sponges, weathering out on the surface. In another bed an *Orbitoides* occurs (probably *O. dispansus*, the common eocene species). No *Alveolinæ* were observed. These beds appear to be the lowest of the eocene system, and very nearly on the same horizon as the limestone breccia mentioned in the last paragraph. Beneath them is a considerable thickness of dark grey or black limestone, traversed for some distance by the stream, which runs at this spot, the narrowest part of the pass, nearly parallel with the strike of the beds. Towards the base of the limestone is a bed containing large concretions of flint a foot in diameter, and below this bed there is some pisolitic iron ore. Then comes sandy limestone containing rounded grains of silica, and then a great thickness of cream-coloured thin-bedded shaly limestones or limestone shales, in which no fossils could be found. The thickness of the whole, beneath the beds believed to represent the base of the eocene, may perhaps be 500 feet or rather more. The cream-coloured shaly beds are the "variegated limestone shales," and the more massive dark overlying rock the "black compact limestone" of Chapter III.

Upper Bolán Pass.

Opposite the camp at Dozán there is a cliff of the limestones seen in the stream section. At the base are the whitish and grey shaly limestones, having a thickness of probably 200 feet.

Dozán.

From Dozán the road runs west for 2 or 3 miles, passing first over the same limestone shales, and then turns to the south-west at a spot where the strata are much disturbed. Beneath the limestone shales, thick black or blackish limestone, veined with white calcspar, crops out. This rock is clearly the same as the upper portion of the thick cretaceous limestone near Quetta. After 2 or 3 more miles, the road again turns to the north-west, crosses a low ridge of the

blackish limestone, and enters on the Chota Dasht of the map, one of the plains of the Quetta plateau.

Chota Dasht and Dasht-i-Bedaolat.

The "Chota Dasht" and Dasht-i-Bedaolat[1] are broad flat plains, absolutely stoneless in general, although the latter is covered with stones to the northward near Sir-i-áb. They are very barren from want of water, but consist of a fine soil, probably of subaërial origin, and that would doubtless be highly fertile if irrigated.

Road from Darwáza to Quetta.

The road to Quetta from the point where the Chota Dasht is entered runs first north-west, and then nearly north across the plain. The hills north and south of the comparatively narrow strait called Darwáza, (where there is a camping ground called Dasht,) that unites the two plains, consist of the black cretaceous limestone dipping west by north. The hills immediately east of the road, 6 or 7 miles beyond Darwáza, are of the same limestone, upon which, close to the road, white, cream-coloured and purplish shaly limestones rest, overlain by more black limestone, interstratified with some that is brown and some whitish in colour. All dip to the south-west, in the direction of the plain, and no higher beds are seen. There can be no reasonable doubt that the variegated shaly limestones are the same as the beds of Dozán, and in each case, as in the Chehiltan range to the westward, black limestone overlies them. The thickness of the two above the thick black limestone of the hills north-west of Darwáza is probably about 500 feet. Eocene beds should come in above the upper black limestone, and they probably do so beneath the deposits of the Dasht-i-Bedaolat. The same thick black cretaceous limestone appears to continue throughout the hills on the east of the flat as far as Quetta.

Uppermost cretaceous beds north-west of Darwáza.

Hills south of Quetta.

The hills west of the road to Quetta a little south of Sir-i-áb are an anticlinal of pale cream-coloured limestone, very homogeneous in texture, and precisely simi-

[1] Little flat and Poverty flat. The latter is a much closer equivalent for *Dasht-i-Bedaolat* than Sir R. Temple's translation "Vale of Poverty."

lar to the hippuritic limestone of Persia. These beds must underlie the thick black limestone, which comes in again to the westward, and forms the Chehiltan range, on which some notes will be found in the next chapter.

CHAPTER V.

NOTES ON THE NEIGHBOURHOOD OF QUETTA.

Position of Quetta.

The town of Quetta stands in a comparatively fertile plain, drained by the tributaries of the Lora river. As usual in all Central Asiatic plains, the margins are stony and formed of a slope of detritus washed from the neighbouring hills. Quetta stands at the base of the slope forming the eastern margin of the plain.[1]

Peat.

Some peat[2] occurs about half a mile west of the station at Quetta, and occupies a considerable area of marshy ground. The peat is not very pure, as it is somewhat mixed with earth, but it closely resembles that found in Europe. None was traced in process of formation.

Miri or citadel.

The Miri or citadel of Quetta is on the top of a mound, rising 50 or 60 feet above the plain. A gallery driven by the military engineers through this mound, near the

[1] Griesbach (*l. c.*, p. 38) describes the valley of Quetta as "a trough formed by the natural flexure of the cretaceous limestone beds." He adds: "The basin so produced is now filled with alluvial deposits, but this of course does not interfere with the collection of water, which gradually fills the basin and may now be found within a few feet of the surface soil." I doubt if this explanation is quite correct. I suspect that part of the valley is underlain by eocene beds, resting upon the cretaceous, and it seems to me possible at least that the occurrence of water close to the surface (some issues in the form of springs) at Quetta itself may be due to the circumstance that some of the alluvial deposits do interfere with percolation. The water is probably derived from the gravel slope to the eastward, and may be brought to the surface, because it is prevented from descending further by impermeable beds in the deposits of the plain, and not because it is contained in a basin of so permeable a rock as limestone. With reference to this question, it should be remembered that in Griesbach's figures, page 37, the heights are on a very much larger scale than the horizontal distances, the former being proportionally about ten times as great as the latter.

[2] This peat was shown to me by Dr. Fullarton, Residency Surgeon.

base, shows that the whole hillock is of artificial origin, for fragments of pottery and bones of domestic animals are found throughout. Some other hillocks of similar form, but smaller size, in the neighbouring plain are also probably artificial, and formed by the remains of buildings.

Localities visited near Quetta.

Time only allowed of a visit to three localities in the neighbourhood of Quetta. These were—(1) the Gházíaband Pass across the Mashalak range, 12 to 14 miles north-west of Quetta; (2) the northern portion of the Chehiltan range, about 4 miles west of Quetta; and (3) the base of the Takátu range, north of the town.[1]

Gházíaband Pass.

1. The Gházíaband Pass is on the road from Quetta to Kándahár. Ascending from Mehtarzái on the Quetta or eastern side of the range, the first inclined bed seen is a gravel, dipping at 5° to the eastward, and containing numerous subangular blocks of black limestone. Beneath this bed, which may possibly be of post-pliocene age, are Siwalik sandstones, usually light brown, and clays, drab, light brown, Indian red or greenish-white in colour. Some conglomeratic bands also occur, and gypsum is interspersed throughout the beds. It usually occurs in flakes with a fibrous structure, filling cracks in the sandstone and clays,[2] and a considerable quantity is procured from this neighbourhood for building purposes. Further down in the section, the clays are less abundant and the sandstones very conglomeratic, the pebbles being occasionally subangular. Many of the pebbles are of limestone, sometimes with nummulites. As already pointed out in Chapters I and III, there appear good reasons for classing all these beds as Upper Siwalik.

Siwaliks.

Towards the western side of the pass eocene beds appear. They consist of vertical[3] shales and limestone, striking north-north-east to

[1] Several details concerning the sections seen at these localities have already been given in Part I, Chapters I and III. In the former the main points are mentioned, in which I differ from Griesbach's interpretation of the geology.

[2] Griesbach mentions its occurrence also in beds and lenticular masses.

[3] In Griesbach's section (*l. c.*, p. 19) they are represented as nearly horizontal. This section may perhaps not be taken from the road, although, from the description, I should

south-south-west. The shales vary in colour, grey or olive predominating; some are reddish, others light brown, and there is a great variety of tints. The limestone is black, abounding in *Nummulites*, amongst which are *N. spira*, *N. obtusa*, and other species. An *Alveolina* also occurs. All the beds are much hardened, and the shales have polished surfaces and an ancient appearance, almost like slate in some places.

Eocene beds.

2. The beds of the Chehiltán range, which forms the western boundary of the plain south of Quetta, have already received a large amount of notice in Chapter III, and incidentally, in the discussion of Mr. Griesbach's observations, in Chapter I.

Chehiltán range.

At the northern extremity of the range there is a rather broad fringe of Siwalik beds.[1] These consist of sandstones, clays, and conglomerates, precisely similar to the beds of the Gháziaband Pass. The pebbles in the conglomerate are very angular.

The Siwaliks rest quite unconformably on cretaceous and eocene beds. The latter are intermediate in character between those of Takátu, where massive limestone of great thickness overlies thick shales, and those of Gháziaband. The limestones are very flaggy, and much interstratified with shale. There is a great thickness of these interstratifications resting upon a thick belt of shale. The shale is not so much hardened, as it is 6 miles further west in the Gháziaband Pass.

The eocene beds overlie cretaceous rocks; the general dip is to the westward, and the latter form for a long distance a detached ridge bordering the Quetta plain. A peculiarly good section of the uppermost cretaceous beds is seen in the gap cut by a small stream which runs out into the Quetta plain just north of the village of Karani. This is the section described and figured by Mr. Griesbach.[2] The following notes

have supposed this to be the case. The disturbance of the eocene beds in general in this neighbourhood is, however, greater than is represented in the figure, and the dips are higher.

[1] Their occurrence was recorded by Griesbach, who looked upon them as Gáj.

[2] *L. c.*, p. 35, fig. 7, p. 37, and Plate IV, Profile 1.

take necessarily more or less the form of a commentary on his description. The rocks are described in ascending order.[1]

Section near Karani.

Cretaceous 3. 2 (1).—The lowest rock seen is the thick blackish limestone extending all along the base of the range, and identical with that forming the hills east of the plain from Darwáza to Quetta, and that crossed in the Upper Bolán between Dozán and Darwáza.

Cretaceous 2. 3 (2, 3, 4 and 5).—These, the variegated limestone shales, are a well-marked assemblage of calcareous shales and shaly limestones, chiefly white or cream-coloured, but variegated with purplish red. These beds appear to be at least 500 feet thick, and are apparently identical with those mentioned in the last chapter as being seen 6 miles north-west of Darwáza, and with those of Dozán in the Upper Bolán Pass. As will be shown hereafter, similar beds occur near Kach, north-east of Quetta.

Cretaceous 1. 4 (6).—Above the variegated limestone shales is a black, hard, compact limestone about 150 feet thick, and, from its hardness and dark colour, conspicuous at a distance, and forming a well-marked dark band[2] along the crest of the detached range of cretaceous rocks already mentioned. By Mr. Griesbach this bed is described as "black, hard dolomitic limestone of great thickness ..... filled with small *Ostrea*." The thickness, however, is considerably less than that of the subdivisions immediately above and below, although the band itself considered as a single homogeneous bed is unusually thick. At the locality examined, the fossils occurring in this black limestone are not well marked, some may be oysters, some are small *Foraminifera*, but the rock, where I saw it, is not "filled with *Ostrea*."

The little stream along which the section is seen has cut a narrow channel through the hard limestone band, and after traversing the small pass thus formed, which runs east and west, the path enters a compara-

[1] The Roman numerals refer;—the first, not in brackets, to Griesbach's section, p. 34, of his memoir, and figures 7 and 8, p. 37; those between brackets to the section on p. 35. The prefix in italics refers to the section in Chapter III of this memoir.

[2] As shown in Griesbach's Plate IV, Profile 1. The bed is there called *Ostrea* limestone.

tively broad north and south valley between the partially detached ridge of cretaceous beds and the main eocene range. This valley is entirely cut out of the lower eocene beds.

Lower Eocene, 5 (7).—The beds exposed in the valley are the usual olive shales of the eocene system. A few bands of grit, weathering of a brownish tint, are intercalated with the shales, which decompose at the surface into a soft argillaceous substance having a superficial resemblance in both colour and consistency to decomposed basalt. These shales dip at an angle of 45° or rather more. The whole breadth of the valley is at least one-third of a mile, probably, on an average, nearly or quite half a mile, and the thickness of the shales cannot be less than 1,300 feet, and may be 1,800 or more.[1]

Eocene, 6 (8, 9, 10, and 11).—Above the olive shales there is a great thickness of shaly and flaggy limestone, sometimes sandy, especially towards the base, and but rarely fossiliferous. These beds form the range west of the valley occupied by the lower eocene shales, the main range in fact. About 500 feet were cursorily examined, but there is a much greater thickness exposed, and there appears good reason to believe that the rock is the same as the nummulitic limestone of Takátu, and of the Bolán Pass, but more shaly and less fossiliferous.

South base of Takátu.

3. The great mass of Takátu, rising to a height of 11,375 feet above the sea and 5,570 above the Quetta plain, consists mainly of nummulitic limestone. At the base of the steep scarp, which forms the southern declivity of the mountain and the northern boundary of the Quetta plain, the soft olive eocene shales are well exposed. They are very thick, apparently considerably thicker than in the section of the Chehiltán range just described, and contain some sandy or gritty beds, a few bands of calcite, and occasional intercalations of impure limestone, one of which, of a brown colour, precisely resembles that at the base of the eocene system in the Bolán Pass, not only in

[1] It will thus be seen that Griesbach has under-estimated the importance of this subdivision, which, in his figs. 7 and 8, p. 37, is represented as inferior in thickness to the hard dark limestone beneath it. For further remarks on these shales see Chapter I of this memoir.

colour and structure, but in containing, in abundance, small *Nummulites* and *Operculinæ*. Under Takátu, however, the bed appears to be intercalated in the shales, not at the base of them.

The same shales, weathering into clay at the surface, continue all along the base of the range, from a point considerably west of a line drawn due north from Quetta, to the Sarakula valley, which they occupy exclusively. No cretaceous bed could be found north-west of the Harnai route.

CHAPTER VI.

NOTES ON THE ROUTE FROM QUETTA TO SIBI VIÂ HARNAI.

Sarakula valley, to south-east of Takatu.

The road from Quettá to Harnai runs for some miles north-east across the plain, and then enters the Sarakula valley, which is entirely composed of lower eocene olive shales, the continuation of those seen at the base of Takátu. With these shales are associated greenish sandstones, sometimes passing into coarse grit and even into conglomerate. The sandstone is usually soft, but some hard brown calcareous rock occurs that stands out from the soft shales. The more ordinary soft form weathers into a mammillated surface, like that of some Siwalik sandstone. Beds of limestone are also interstratified with the shale; one conspicuous vertical band, a few miles from the entrance to the valley, abounds in *Nummulites* of several species, comprising *N. granulosa*, *N. spira*, and a form allied to *N. brogniarti*, together with *Alveolina*, *Orbitoides*, and large *Orbitolites*, more than an inch in diameter.

Limestone in shales.

Limestone of Takatu.

The nummulitic limestone of the great hill mass of Takátu, forming the north-western slope of the valley, overlies the shales, but, as is so commonly the case, where a hard massive formation rests upon soft, argillaceous beds, enormous blocks, even hills, of the limestone, appear to have slipped down upon the shales, so that the relations of the two are, in places, very difficult to understand, for the shales

Slips.

are much contorted and frequently vertical. On the south-eastern side of the valley, near Gandak, the usual camping ground for travellers halting between Quetta and Kach, a thick band of limestone, intercalated in the shales, comes in dipping south-east, or in the reverse direction to the beds north-west of the valley. This limestone band, however, a little further to the south-east, turns up again and dips north-west, forming the high ridge over 9,000 feet high (*i. e.*, above the sea), called Nar on the map. The uppermost cretaceous beds probably come in on the opposite or south-east side of this ridge.

Ridges south-east of valley.

Some of the shales near Gandak are red instead of olive. Sandstone beds become more abundantly developed further up the valley; some of these sandstones being gritty and even conglomeratic. Amongst the coarser as amongst the finer beds all the material appeared to be sedimentary.

Sandstones.

In places, resting unconformably on the eocene beds, there are enormous masses of conglomerate, often turned up and dipping at high angles. Here and there this conglomerate appears to have filled the valley at one time. Hills formed of this rock, with the bedding nearly, if not quite vertical, are seen to the north of the spot where the road leaves the Quetta plain, and a ridge of considerable height, immediately west and south-west of the camping-ground at Gandak, consists of the same formation. This conglomerate is evidently of comparatively late origin; it abounds in nummulitic limestone pebbles, most of them well rolled, and it precisely resembles the uppermost Siwalik conglomerate, to which it probably belongs.[1]

Siwalik conglomerate

The road beyond Gandak, after pursuing a north-east or north-north-east direction for several miles, turns abruptly to the south-east, and then to east. Just where the turn takes place, on a hill crossed by

[1] The same conglomerate, as already mentioned in Chapter III, is said to cap Zarghun mountain, a few miles to the south-east. My information is derived from Sir. C. E. St. John. The occurrence of conglomerate on Zarghun was observed by Captain Harvey of the Trigonometrical Survey.

this trouble, a thick bed of conglomerate appears, dipping 60° to 70° to the southward. This bed continues for a long distance towards Kach, south of the road.

Cretaceous limestone, shales, &c.

Soon after the change in the direction of the road, variegated limestone shales, apparently the same as the cretaceous beds of Dozán, the Chehiltan range, &c., crop out from beneath the olive eocene shales north of the road, and continue to Kach. Beneath the limestone shales dark limestone appears, and a peculiar blackish rock, apparently decomposed basalt, is associated with them.

Position and geology of Kach.

The fortified post of Kach is situated at the junction of several important routes traversing the valleys that meet at this spot. The village of Kach is between 2 and 3 miles distant to the north-east, and Amadun is 2 miles further in the same direction.

The Valley of Kach[1] is composed of the eocene olive shales, which in this direction, and indeed throughout the route from Quetta to Harnai appear gradually to increase in thickness. The great mass of hills to the eastward, part of the Pill range, is of nummulitic limestone, apparently overlying the shales. To the north-west of the Kach valley is a ridge, the continuation of the belt of cretaceous beds seen north of the road from Gandak, but this belt north of the fortified camp rises into a range of considerable height. It sinks again at Amadun, but rises again higher than before to the east of Amadun, and forms part at least of the Bibai range.

Section of cretaceous beds near Kach.

A path runs from the camp at Kach to the north-west across the cretaceous ridge, and further on joins the road to Gwál, in Pishin. The path crosses lower eocene

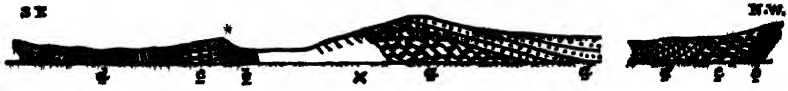
[1] Unfortunately fever on the road from Gandak to Kach, and whilst at Kach, seriously interfered with my power of making observations in that neighbourhood, and throughout the route as far as Harnai. This was particularly unfortunate, for the geology is very interesting, and not only was I prevented from visiting some localities that I might otherwise have seen, but my observations, even of the places examined, were imperfect. I was obliged to leave the question of the unconformity of the eocene beds upon the supposed cretaceous and the manner in which the thick limestone of Takkim and Zarghun appears to dip each and another great mass, lower in the system, to come in to the eastward, very inexplicably explained.

shales for some distance, and amongst them a conspicuous bed of conglomerate. The pebbles are much larger than usual, and consist of sandstone, grit, limestone and chert, many fragments of the latter being angular. No basalt, nor any other volcanic fragments, could be detected, and this is interesting, as marking the contrast to the conglomerate near Amadun to be noticed presently.

The olive shales and sandstones dip at first to the south or south-east; further to the north-west they become vertical, and are succeeded, apparently in regular descending order, by variegated limestone shales, white and purplish red in colour, and dipping north-west at a high angle. This is probably a reversed dip, and the limestone shales are much crushed. They look a little different from the limestone shales near Quetta, probably in consequence of the greater amount of disturbance, but there can be very little doubt of their being the same beds.

The next bed is not so well seen. It is a homogeneous rock, very dark coloured, apparently a decomposed basalt (anamesite). This is followed by nodular light grey limestones dipping north-west at a much lower angle, but somewhat contorted. Above these limestones, dipping at a still lower angle and quite unconformable to them, are dull greenish sandstones, precisely similar to those associated with the lower eocene shales, and almost certainly belonging to that group. To the north-west of the ridge, however, neither shales nor conglomerates were observed, although both occur to the south-east only a few hundred yards away.

Unconformable superposition of eocene on cretaceous rocks.



Sketch section showing unconformity between eocene and cretaceous beds near Kach: *a*, cretaceous limestone; *b*, basalt; *c*, variegated limestone shales; *d*, lower eocene; × probable anticlinal, perhaps faulted.

Proceeding to the north-west the path passes over a plain, on which the sandstones continue for a mile or two, dipping at low angles, then there is a synclinal curve, and a little further on the variegated lime-

stone shales crop out once more. Here, again, the eocene sandstones appear to be unconformable to the underlying beds. At this place true basalt is associated with the variegated limestone shales, whether it is interstratified or intrusive is not so clear, but the appearances are in favour of intrusion.

In the accompanying sketch an attempt has been made to represent this very interesting section; the sketch is copied from my note-book, and merely records what was seen, without attempting to explain it. If, as appears most probable, the sandy beds to the north-west of the cretaceous limestone ridge are the same as the shaly beds to the south-east, there is evidently a very sharp anticlinal of the underlying cretaceous rocks, probably complicated and rendered indistinct by faulting.

Ridge north-west of Kach valley.

As already remarked, the ridge of cretaceous rocks to the north-east of the section just described rises to a considerable altitude along the north-western side of the Kach valley, the variegated limestone shales continuing nearly vertical throughout. The crest of the range is formed by the nodular grey limestone, and between the two limestones basaltic rock is seen in places and may be continuous throughout.

Hills east of Amadun.

East of Amadun, this band of basaltic rock assumes large proportions and is conspicuous from a distance, forming a broad dark band on the hill side. The character, however, appears to be greatly changed. About 8 miles east-north-east of Kach village and 2 miles east of Amadun, the following is the section exposed. At the base of the olive shales there is the typical limestone breccia of the lowest eocene beds, dark angular limestone fragments in a rather paler calcareous matrix, as near Mach, in the Bolán, at several places in the Sulemán range, and elsewhere. Here the breccia contains *Alveolina* and other *Foraminifera*, but no *Nummulites* were observed. This bed is nearly or quite vertical. Then come the variegated limestone shales, and then the volcanic band, here consisting entirely of a coarse conglomerate.

Conglomerate of basaltic pebbles.

bles and matrix are both entirely derived from volcanic rocks; the

pebbles vary much in constitution—all appear to be doleritic, but some are ordinary basalt, some are prophyritic, many contain black crystals, apparently of pyroxene, others consist of anamesite. All are rolled thoroughly; the size varies, some being a foot in diameter, but the majority measure from 3 to 6 inches.

Limestone of Bibai range.

This conglomerate can scarcely be less than 1,000 feet in thickness and it may be more. The upper part of the hill consists of hard massive limestone, apparently resting on the conglomerate, but really, in all probability, inferior to it; the dips here, as near the Kach camp, being inverted. In the limestone are some obscure *Foraminifera*, but no *Nummulites* nor *Alveolina* could be detected. The limestone must be very thick; it forms all the upper portion of the Bibai range near Amadun.

These sections, it should be remembered, afford the first instance hitherto observed on the western frontier of India of unconformity between eocene and cretaceous beds.

Road eastward from Kach.

From Kach post the Harnai road runs east-south-east to Manji, along a valley composed of eocene olive shales, having, in general, a southerly dip, whilst the Pill range to the north is composed of nummulitic limestone.[1] This limestone, as already stated, appears to overlie the olive shales of the Kach valley, but towards Manji the massive limestones of the Pill range to the northward appear to dip under the shales of the valley and to rise again from beneath the latter to the southward, and to form the anticlinal hog-backed range traversed by the road at the Chappar rift. This rift, which is simply a gorge cut through the limestone range by the stream from Kach, has already been described, so far as the limited observations made when traversing it at night allowed, in Chapter II. The uppermost beds traversed are undoubtedly nummulitic, and so, probably, are all the rocks exposed in the gorge, but lower strata may be cut into.

Chappar rift.

[1] I was suffering from fever and obliged to travel in a doolie, so the observations on this portion of the route are of doubtful accuracy.

After traversing the Chappar rift the road runs from Dargi almost to Spintangi, a distance of nearly 50 miles, in an east-south-eastern direction parallel to the strike of the beds, and passes along a broad valley formed by the olive shales of the eocene and their associates. In this valley are the military stations of Shâhrág or Shárigh and Harnai. Although the valley is continuous throughout, all the streams draining it break through the hills to the southward, showing, as already noticed in Part I, Chapter II, that the course of the streams must be of greater antiquity than the present form of the surface.

Valley of Shâhrág and Harnai.

The range north of the valley, the continuation of that through which the Chappar rift runs, gradually rises to the eastward to a great height, amounting, north of Shâhrág, to 11,440 feet above the sea, according to the determinations of the Topographical Survey, and upwards of 7,000 feet above the Shâhrág plain. Immense limestone cliffs are seen in this range, and it is very probable that part of the rocks composing it are older than eocene. Further east, the range again sinks into a hog-backed ridge, apparently a simple anticlinal.

Range north of Shâhrág.

The range south of the valley consists of alternations of sandstone and shale with some beds of limestone. The general dip is south or south-west, but the angle, west of Shâhrág, is not high. The same, rather low, south-westerly dip is found in the valley, except near the northern range, where the angle of inclination is higher. The thickness of the beds exposed in the southern range (Bilen Pingi on the map) can scarcely be less than 2,000 feet, and probably as much more crops out in the valley itself.

Range south of valley.

At Shâhrág the plain is unusually broad from north to south, and is very much covered with sub-recent deposits of gravel, sand, and clay.

Shâhrág (or Shárigh) is the locality already noticed where the occurrence of coal has been reported.[1] The spot where this coal occurs is

[1] For a description of the economical value of the coal, see Rec. Geol. I., 1862, Vol. XV, p. 169.

about 3 miles south of the village and of the military station, on the feeders of a stream called the Siah Dad. A good section is seen in a small watercourse that joins the main stream from the right or western side just above the spot where the latter cuts its way through the hills to the southward. The beds are vertical or nearly so. The following measured section is in descending order, and commences to the south, close to the main stream.

Section of Coal-beds near Shâhrig.

	ft.	in.
1. Light greenish-grey calcareous sandstone	1	4
2. Impure grey sandstone, with fragments of shells	0	8
3. Olive-grey shale	5	0
4. Grey limestone	0	4
5. Light brown calcareous sandstone	2	2
6. Olive grey sandstone	1	3
7. Sandstone, calcareous in parts	0	7
8. Soft olive-grey sandstone	1	9
9. Do. with a few obscure shales	1	3
10. Not seen (probably soft shale)	15	0
11. Olive-grey sandstone, some of it hard, containing in places nodules of fawn-coloured clay	4	8
12. Olive grey marl, abounding in *Ostrea*, *Cardita*, *Turritella*, and other shells	2	0
13. Bluish-grey shale, with some calcareous nodules in the upper portion	4	0
14. The same, with bands 3 inches to a foot thick, of rather calcareous sandstone	7	6
15. Grey shell marl, full of shells, *Turritella* and various bivalves (*Lamellibranchiata*) crushed and undistinguishable	0	10
16. Carbonaceous shale apparently pyritous (much decomposed)	0	8
17. Impure limestone with carbonaceous bands full of shells (undistinguishable)	0	3
18. Carbonaceous shales	1	0
19. Brown clay	0	3
20. Carbonaceous clay	0	4
21. Impure shaly limestone	0	3
22. *Coal*	0	3
23. Carbonaceous shell marl	0	5
24. Shale, more or less carbonaceous	2	3
25. Sandy shale, with hard nodular calcareous bands	2	0
26. Carbonaceous shale (decomposed), apparently containing much pyrites originally. (*N. B.*—In these beds all the pyrites have decomposed and are represented by a yellow deposit.)	1	

	ft.	in.
27. Soft grey shale	1	9
28. Hard calcareous and nodular shale	0	10
29. Shale, sandy in parts, carbonaceous in others	5	0
30. Shell marl, carbonaceous	0	3
31. Olive grey shale, rather carbonaceous in parts and containing a band of hard nodular limestone	20	0
32. Shell marl	0	2
33. Carbonaceous pyritous shale	0	4
34. *Coal*, about an inch good, the rest shaly	0	5
35. Carbonaceous pyritous shale	1	0
36. Red sandy clay, full of bivalve shells	0	1
37. *Coal*	0	4
38. Grey marl, abounding in *Ostrea* and other bivalves	0	3
39. Soft olive-grey shale, with harder marly beds abounding in shells	2	0
40. Shale, in part highly carbonaceous, with a thin band of nodular limestone	3	0
41. Impure nodular limestone, sandy in part	3	0
42. Soft grey shale with some calcareous nodules	2	6
43. Shell marl	0	1
44. Soft grey shale	0	9
45. Impure nodular limestone	0	7
46. Shale, carbonaceous in parts	3	6
47. Impure nodular limestone	0	8
48 Shell marl passing into limestone	0	9
49. Carbonaceous shale and a little coal	0	3
50. Limestone full of shells	0	1
51. Shale, rather carbonaceous, with a thin band or two of coal	2	2
52. Coal and shale interstratified, very pyritous apparently	1	4
53. Soft grey shale, with nodular limestone bands and one or two very thin beds of shell marl	16	0
54. Sandy shale, with some impressions of stems of large plants	1	2
55. Nodular limestone, flaggy, with numerous bivalve shells, *Turritella*, &c, seen in section	1	4
56 Carbonaceous shale, with thin layers of coal	1	9
57. Shell marl passing into limestone	1	0
58. Shale, highly pyritous	5	0
59. *Coal*, mostly pure, but with one or two thin shale partings	0	10
60. Shale, very carbonaceous in parts	6	0
61. Shell marl	0	7
62. *Coal*	0	2
63. Carbonaceous shale, with one or two thin seams of coal	5	3
64. Impure limestone with some shells	0	4
65. *Coal*	0	1
66. Carbonaceous shale	0	1

		ft.	in.
67.	*Coal*, good in general, a small portion earthy. (*N. B.*—This is one of the seams used for fuel, and of which a sample was taken for analysis.[1])	1	9
68.	Sandy shale and sandstone	25	0
69.	Shale, more or less carbonaceous, and some nodular limestone	5	0
70.	*Coal*, mostly good	1	0
71.	Shale	2	9
72.	*Coal*	0	8
73.	Shale	5	6
74.	Impure *coal*	0	2
75.	Carbonaceous shale	0	9
76.	*Coal*	0	4
77.	Shale	10	0
78.	Shale and coal intermixed	1	0
79	Shale	3	6
80.	Shell marl	0	2
81	Shale, containing nodular bands and one or two thin seams of *coal*	25	0
82.	Shell marl	0	2
83	Coal	0	1
84.	Shale	0	7
85	Nodular limestone	5	0
86	Shale, with thin layers of *coal*	21	0
87.	*Coal*	0	8
88.	Shale	5	0
89	Nodular limestone	1	0
90.	Shale	14	0
91	Shell marl, with large bivalve shells	0	6
92	Carbonaceous shale	0	5
93	*Coal*	0	4
94.	Shell marl	0	2
95	*Coal*	0	2
96	Shale	0	2
97.	*Coal* and shale intermixed	1	1
98	Shale	0	8
99.	*Coal*	0	10
100.	Ferruginous clay and shell marl	0	2
101.	*Coal*	0	7
102.	Carbonaceous shale	0	9
103.	Grey shale, with some nodular limestone	18	0
104.	*Coal*	0	6

[1] Analysis by Mr. F. R. Mallet—

Water driven off at 230° Fahr.	6 8
Volatile matter exclusive of water	40 8
Fixed carbon	47 6
Ash	4 8
	100

		ft.	in.
105.	Shale	0	6
106.	*Coal*	0	4
107.	Shale and sandstone badly seen	18	0
108.	Sandstone containing nodules	2	6
109.	Shale	2	8
110.	Grey shaly limestone	0	3
111.	Shale	2	4
112.	*Coal*	0	4
113.	Grey shale	0	1
114.	*Coal*	0	1
115.	Grey shale	3	6
116.	Soft grey sandstone	0	3
117.	Shale	0	3
118	Nodular limestone	1	8
119.	Sandy grey shale and limestone	7	6
120.	Sandy shale, very carbonaceous below, with large shells	0	8
121.	Earthy *coal*	0	5
122.	*Coal*, with calcareous bands interstratified	0	6
123.	Grey sandy shale	1	2
124.	Carbonaceous shale	0	2
125.	Sandy shale	0	8
126.	Carbonaceous shale and a little *coal*	0	8
127.	Sandstone, shaly in parts	16	0
128.	Hard shale with layers of coal	0	6
129.	*Coal*, good	1	1
130.	Shale, with limestone nodules	3	6
131.	*Coal*, good	0	3
132.	Carbonaceous shale	0	6
133.	Shell marl	0	2
134.	*Coal*	0	2½
135.	Shell marl	0	2½
136.	*Coal*	0	6
137.	Shell marl	0	1
138.	*Coal*	0	3
139.	Shale	2	6
140.	*Coal*,[1] good	0	8
		361	6

The beds are very similar to those of Mach in the Bolán, as may

[1] An analysis of the coal from this seam by Mr. Mallet gave—

Water driven off at 230° Fahr.	3 0
Volatile matter exclusive of water	42 3
Fixed carbon	46 1
Ash	8 1
	100

be seen by comparing the section just given with that measured by Mr. Griesbach.[1] It is remarkable that fossil shells, usually rare in the olive shales, should occur in both localities in abundance in the beds associated with the coal.

Resemblance to Mach beds.

In the hills to the south, the beds resting upon the shales associated with the coal dip southward at a low angle, and consist of shales with intercalated limestones. Three-quarters of a mile to the north more coal outcrops are seen, probably the same seams repeated by a roll of the strata. Again the beds are vertical or nearly vertical. At this place one seam was traced, and found to thin out within a short distance, about 350 yards, from a foot in thickness to a mere layer or two in carbonaceous shale.

Hills south of section.

A few miles from Shâhrág, on the road to Harnai, the road descends to a valley, chiefly cut through subrecent conglomerate. East of Shâhrág, although the valley-like depression that marks the outcrop of the olive shales continues, the outlines are less regular. The shales appear at intervals. In this direction they are much variegated with different colours,—brownish-red, yellowish-brown, &c., and some are claret red. Beds of varying thickness, from a foot to twenty or thirty, come in, composed of hard grey and olive sandstone, fine grained in general, sometimes enclosing fragments of clay, and well stratified. These beds weather into angular blocks. One band of limestone is seen, weathering of a buff colour, and abounding in large nummulites (*N. elatus* and other species). In some places coal seams are exposed close to the road; they are always thin, and are probably a continuation of the Shâhrág beds. The dips as a rule are very low, often nearly or quite horizontal.

Rocks of valley between Shâhrág and Harnai.

From Harnai to near Spintangi the same beds are seen, the nummulitic limestone forming an anticlinal ridge to the northward, and the shales occupying the plain

Harnai to Spintangi.

traversed by the road. Shortly before reaching Spintangi, the road turns southward, on the bank of a large stream bed, a tributary of the Nári river. To the east of this stream, the limestone forms two or three parallel anticlinal ridges with an east-south-east—west-north-west strike. The most southern of these anticlinals terminates close to the road, and there is a warm spring from which sulphuretted hydrogen is given out at the western end of the ridge. South-west of the base of this hill, a moderate thickness of olive shales is seen, probably 500 to 1,000 feet, resting of course on the limestone of the hill; then the beds become vertical, and a thick band of nummulitic limestone, containing *Nummulites* and *Alveolinæ* in abundance, forms a low ridge running north-west—south-east. The stream cuts its way through this ridge and enters the valley of Spintangi, which is about a mile broad, and composed of vertical olive shales.

Siwalik conglomerate south-west of Spintangi.

The valley of Spintangi runs north-west—south-east, between the ridge of nummulitic limestone just mentioned and another ridge, south-west of the valley, formed of Siwalik conglomerate, exactly resembling the bed found usually at the top of the Siwaliks, and dipping 70° to 80° to the north-east; no nummulitic limestone occurs at the junction; the Siwaliks are in contact with olive shales. The conglomerate abounds in limestone pebbles, many of them black, and resembling the rocks of the upper cretaceous beds; some fragments of hard sandstone, chert, and jasper also occur. The largest pebbles are 5 to 6 inches in diameter.

Peculiar mode of occurrence.

The relations of the conglomerate are not clear. Appearances are in favour of its being the bottom bed of the Siwaliks of this locality, of its resting with pseudo-conformity upon the eocene shales, and of the dip to the north-east being reversed. It is in favour of this view that the next Siwalik beds seen to the southward have a south-westerly dip. There is just a possibility that the conglomerate here, as near Pir Choki, although in contact with eocene rocks, is the highest Siwalik bed, and that the peculiarities of the dip are due to the rocks of the two systems having

been crushed together; but this is less probable than the other view, and appears to be in opposition to the evidence at Tung.

Junction of eocene and Siwaliks at Tung.

At Tung, 12 miles south-east of Spintangi, and on the road from Sibi *vid* Gandkindaf to Thal Chotiali, the junction of eocene and Siwalik beds is very similar to that at Spintangi, except that no massive band of conglomerate occurs. The "Tung," or defile, is produced by the Bheji river, another tributary of the Nári, which cuts its way through a band of limestone, evidently the same as that seen north-east of Spintangi, but thicker, being probably not less than 1,000 feet thick. The limestone is well bedded, and dips at a very high angle, about 80°, to the south-west; it contians in abundance *Alveolina* and *Nummulites* (*N. obtusa*, *N. spira*, and other species), and it has olive shales both overlying and underlying it. Beneath the underlying shales, as north of Spintangi, limestone crops out at no great distance and forms a high dome-shaped hill, apparently an anticlinal. The eocene shales above the limestone have sandstones intercalated, and are of no great thickness, being apparently much thinner than at Spintangi. They are vertical and are succeeded to the south-west by Siwaliks, reddish-brown clays, and light brown sandstone with bands of conglomerate. A little further to the south-west, the dip of the Siwaliks becomes gradually lower and to the south-westward. Here, again, there is pseudo-conformity between the eocene and Siwalik beds, although the conglomerates of the latter are full of nummulitic limestone pebbles.

Road from Spintangi to Sibi.

From Spintangi to the plain north of Sibi, the road preserves a general south-western direction, almost at right angles to its course from Kach to Spintangi. Siwalik beds are traversed throughout the whole distance, about 20 miles in a direct line. A considerable portion of the route is along the Nári river.

Siwaliks near Gandkindaf.

On this road, after leaving Spintangi and crossing the conglomerate ridge, the Siwaliks dip at first to the south-west, then they become horizontal, and then dip north-

west. This continues for some miles, as far as Gandkindaf. Here there is another of the peculiar valley-like plains, so characteristic of these hills, running east-south-east—west-north-west. On the northern side of the plain, the dip of the Siwaliks is irregular; at Gandkindaf it is to the north-east at a high angle, 60° to 70°, but some distance further east it is in the reverse direction, to the south-west. South of the plain the dip is north-north-east, and the rock is a coarse conglomerate of great thickness. It is probable in this case that the conglomerate is the uppermost Siwalik bed, for beneath it there is a very great thickness of sandstone and clays seen in continuous section, though it is far from clear how the uppermost conglomerate can be here in place, for, as has been just shown, the beds on the opposite side of the plain at Gandkindaf dip in the same direction, north-east, and should consequently be higher. These beds too are overlain by several thousands of feet of Siwalik strata. But it is quite possible that the opposite or south-west dip seen east of Gandkindaf is continued beneath the plain; and if this be the case, all the rocks seen to the northward may roll over, and the conglomerate, although the highest in the system, may come in naturally, or there may be a fault corresponding in direction with the valley.

Section in Nári river.

Below the conglomerate, which is of considerable thickness, the usual light brown sandstones with some conglomerate bands come in with a very steady north-north-east dip of about 20°. This continues for some miles. About Kelat-i-Kila there is more irregularity, the rocks are somewhat crushed and contorted. Gradually lower beds come in, only differing from the upper in containing more clay. Gypsum in flakes is not infrequent. On approaching the plains the beds turn over, and dip southward at high angles[1] in the Nári gorge near the edge of the hill country. The uppermost beds, including the conglomerate, do not appear to be exposed south of the anticlinal.

[1] These are the beds very correctly figured and described by Mr. Griesbach, *l. c.*, p. 12, and Pl. I, figs. 2, 3, and 4.

Throughout all these sections, from Spintangi to Nári bungalow at the entrance of the gorge, and within 7 miles of Sibi, all the beds seen are Upper Siwalik (or Manchhar), not a trace of the characteristic strata belonging to the lower division of the Siwalik system is exposed.

All beds Upper Siwalik.

CHAPTER VII.

NOTES ON THE ROUTE FROM SIBI TO JACOBABAD VIÁ PULAJI AND SHAHPÚR.

The road from Sibi to Jacobabad is near the eastern border of the Kachhi, and traverses flat alluvial ground, mainly desert, throughout, except at one spot close to Mal, and only 12 miles south-south-east of Sibi, where a very low ridge of Siwaliks is crossed. The beds of this ridge consist of sandstone dipping at a very low angle, about 5°, to the northward. Instead of following the direct road, however, between Pulaji and Shahpúr, some of the hills to the eastward were traversed, and visits were also made to the ranges near Lehri.

General course of road.

Siwaliks near Mal.

All the hills along the border of the plain are Siwalik, but nummulitic limestone, easily recognised at a distance by its colour and by the form of the ridges, appears at a very short distance inside the outer range in many places; there is one large hill due east of Nári bungalow, another east-by-south from Mal, another again east of Lehri.

Nummulitic limestone hills to eastward.

At the spot where the Lehri stream leaves the hills, the Upper Siwalik conglomerate is seen dipping at a high angle, 60° or 70°, to the south-west. Here the hills were found to be inaccessible, but some miles further south, the Siwaliks were seen to rest on the nummulitic limestone. At the base of the former are some brightly coloured clays, and above these grey sandstone. Both

Ranges east of Lehri.

apparently and the former certainly belong to the lower Manchhars or Siwaliks.

The nummulitic limestone hill to the eastward is one of the rounded anticlinal ridges so common in this part of the country. It is impossible to say whether Siwaliks recur beyond it or not. It is quite possible that the Siwaliks may extend much further to the eastward, east of Mal and north-east of Lehri, than is represented on the map, the lines in this direction being mere guesses.

Rocks between Pulaji and Dingan.

On the road running to the north-east from Pulaji to Dingan, a halting place a short distance within the hills, near the place where the Ghari stream leaves them, there is much sub-recent conglomerate on the edge of the plain, and the Siwaliks crop out quite unconformably from beneath the newer deposit. They dip south-west at an angle of 30° to 35°, and contain but little conglomerate, the usual massive bed not appearing at the top.

There is a track eastward from Dingan to Sangsila and Dera Bugti.[1] For some miles along this track the Siwaliks have a low northerly dip.

Country east of Dingan.

A range of nummulitic limestone, the continuation of that seen east of Lehri, runs some miles north of the road, and near the base of this range the Siwaliks turn up sharply. Here, as near Lehri, it is probable that Lower Siwaliks are represented. The precise line of junction is obscure, the nummulitics appearing to dip north, and there may be a fault. Further east, towards Sangsila, the nummulitics form an anticlinal, and the Siwaliks are seen to rest upon them, but in this direction also, as will be shown in the next chapter, it is doubtful whether the two systems are conformable.

Rocks south of Dingan.

South of Dingan, between the Ghari and Marwar streams, the Siwaliks dip at about 45° to S. 30° W. and consist of soft brown sandstones and brown clays

[1] The stream from Sangsila and Sehâf (Dera Bugti) does not run out of the hills to the northward of Pulaji as represented on the accompanying map, but further south. The stream to the northward is the Ghari.

with perhaps more gypsum than usual, all in the form of fibrous flakes filling vertical or horizontal cracks, precisely as in the Gházisband Pass near Quetta.

Lower Siwaliks.

From Teghâp, a spot where the Marwar stream runs through a ridge of Siwalik sandstone, a road known as Shekazihâd or Ghorbundzihâd leads to the south-west amongst Siwalik hills. For a short distance this track passes up the bed of the Marwar stream, then it enters the rocky glen of a tributary from the southward. After entering the tributary valley, lower Manchhars or Siwaliks crop out, and a superb section is exposed. The sandstones, instead of being light brown, are grey with interstratifications of clay, dull and rather light Indian red in colour, more or less variegated and often nodular (marly). Frequently rounded masses of the clay occur mixed up with the sandstone. The conglomerates contain no nummulitic limestone pebbles, but are composed of fragments of sandstone and clay, precisely like the materials of the associated strata. There can be no doubt as to the petrological distinction between these beds and the Upper Siwaliks.

At the base of the Lower Siwaliks are about 150 feet of red clay and then about 50 more of yellow: the latter is the colour of yellow ochre when weathered, but greyish-yellow or sometimes pale olive with fine violet streaks when freshly fractured. At one place on the top of the yellow clay there is a bed 6 to 8 feet thick of gypsum, finely crystalline, some portions being the purest white alabaster. Fragments of this occur, of as much as a foot in diameter. Many portions, however, are disfigured by black veins.

Bed of alabaster.

Below the yellow clay is the top of the nummulitic limestone. The section is superbly seen; all the beds dip at about 5°, and there is absolute pseudo-conformity, so far as could be observed, although the Gáj and Nari beds are entirely absent.

Nummulitic limestone.

In the limestone beds two or three species of nummulite occur, one resembling *N. brogniarti*, another apparently a small form of *N. obtusa*,

and, in a bed just beneath the top, *N. biaritzensis* and *Alveolina*.[1] Casts of large species of *Conus*, of *Lamellibranchiata*, &c., are also found.

The remainder of the route between Sibi and Jacobabad presented no features of interest.

CHAPTER VIII.

NOTES ON THE ROUTE FROM JACOBABAD TO HARRAND IN THE DERAJÁT *VIÁ* DERA BUGTI.

The general direction of this part of the route is nearly north-east.

Road from Jacobabad to Gandoi.

For about 25 miles from Jacobabad to Goranári, an outpost of the Sind Horse, alluvium is traversed. About 2 miles north of Goranári low rises appear, covered with nummulitic pebbles, and undoubtedly formed, like similar rises near Sibi, of Siwalik sandstones. These beds are seen in section, a little further to the north-west, dipping north at a very low angle, not more than 2°. They are the usual light-brown sandstone and clay. The same beds re-appear here and there on the road to Suri Kushtak and Gandoi, but generally the country is covered with blown sand, sometimes forming hillocks, as in the desert country east of the Indus.

Zen range of nummulitics.

A couple of miles north of Gandoi, the Zen range of nummulitic limestone appears. It is a long, low anticlinal roll, of no great height anywhere, but highest to the westward. It strikes east and west, and extends west nearly to the extremity of the Bugti hill area, not far from Pulaji, and sinks to the eastward into an elevated plain that stretches away to Gandahári hill. Both to the north and south Lower Siwaliks (or lower Manchhars) rest upon the nummulitic strata, and in both cases, so far as was ascertained, in perfect pseudo-conformity, despite the break between the two.

[1] This is the instance of the occurrence of *Alveolina* in the uppermost eocene beds referred to in Chapter I.

North of Gandoi and for a long distance to the eastward, there is a conspicuous ridge of Siwaliks, escarped to the north and sloping to the southward. This ridge is composed of a thick bed of hard whitish marl, and must nearly correspond to the limit between Upper and Lower Siwaliks. The road from Gandoi to Mand presents the following section of the Lower Siwalik group. The beds beneath the marl are thick strata of grey sandstone (often containing irregularly formed calcareous concretions that weather out upon the surface), conglomeratic beds containing fragments of clay and sandstone, clays and ferruginous beds. Some of the conglomeratic beds contain numerous pieces of bone and occasionally these ossiferous beds are highly ferruginous. The clays, which are subordinate and not largely developed, are yellow or red.

Lower Siwaliks near Gandoi.

Towards the base are several brightly coloured beds. There is first a considerable thickness of yellow sandstone with ferruginous bands, then some grey sandstone, and next a bed of ferruginous grit, one of the usual conglomeratic or gritty beds, composed of small clay pellets in a sandy matrix strongly impregnated with iron. Below this again are variously coloured sands—white, purple, and brown,—the colour changing at short intervals. These are just above the nummulitic limestone. The different beds appear not to be constant over any considerable area.

The fossils found in different beds are not the same. Thus one bed, formed almost entirely of rounded sandy concretions, about half an inch in diameter, abounded in fragments of crocodile and tortoise plates, but no mammalian teeth or bones were observed. Some of the tortoise plates must have belonged to large animals.

Fossils vary in different beds.

A dark-coloured rather ferruginous bed abounded in fossil shells, and yielded the species of *Melania*, *Paludina*, and *Unio* noticed in the third chapter and described in the appendix to this report. Besides the shells numerous bones and some teeth of a *Rhinoceros* were found, but no remains that could be recognised

Molluscs.

as belonging to any other vertebrate. It is of course possible that some of the bone fragments may have belonged to another mammal, but all the teeth found were those of *Rhinoceros*. Just above this bed, in soft sandstone, were the remains of what must have been a perfect or very nearly perfect *Rhinoceros* skeleton. The skull had decayed and only the teeth could be taken, but most of the vertebræ were found attached together, and the lower jaw was in place, a circumstance that alone is almost sufficient to show that the animal must have been buried whole.

Rhinoceros, &c.

The road traversed from Gandoi leads eastward for some miles through the Upper Siwalik area, south of the ridge above mentioned as occurring close to the boundary between Upper and Lower Siwalik beds. The road turns northward and passes through this ridge just before reaching a camping ground called Duzd Kushtak[1] on the margin of the nummulitic limestone rise, here a very low, almost flat, anticlinal roll, the summit of which is a wide open plain known as Dasht Goran (plain of wild asses). The lowest beds of the Lower Siwaliks at this spot comprise ferruginous bands, much resembling laterite, and alternating in places with white sand. The bottom bed is ferruginous, and consequently easily traced in the sections on the sides of ravines, &c. Beneath it are perhaps 50 feet of rather shaly limestone, slightly nodular and containing a small nummulite, apparently *N. ramondi*. Below this limestone are several hundred feet of the usual pale olive nummulitic shale, bands of it in this case, however, being reddish-brown or coffee-coloured. With the shales a few thin beds of impure limestones are intercalated in places (in one locality these were found to abound in *Bryozoa*), and beneath the shales there is thick limestone, forming the surface of the anticlinal rise to the northward, the continuation of the Zen range. Some of this limestone abounds in *Orbitoides* (probably *O. dispansus*), a form with a prominent central boss; many of the individuals are very small.

Rocks near Duzd Kushtak.

[1] A little north of the spot where the name is printed on the map.

Pseudo-conformity of Siwaliks to Nummulities.

The boundary between Siwalik and nummulitic beds was followed for 8 or 10 miles to the eastward from Dusd Kushtak, and could be seen for nearly as many more, the rocks being perfectly distinguishable for many miles in the clear atmosphere. The boundary was also examined for 4 or 5 miles to the westward of the same place. Throughout the whole distance there appeared to be absolute conformity between the two systems, and this was unusually well seen, because of the uppermost nummulitic bed being a band of limestone only 50 feet thick in general. In no single case does this limestone appear to be worn through. It varies in thickness, but the variation is probably due to differences in the original deposition, not to denudation. Some change must take place between Dusd Kushtak and Gandoi (time did not permit of a complete examination of the intervening tract), because no shales are seen beneath the uppermost nummulitic limestone at the latter locality, but there can be very little doubt that the limestone band is much thicker there.

Siwaliks north of Zen range.

To the north of the nummulitic anticlinal, near Dera Bugti, precisely the same beds appear as to the south. The same olive and coffee-coloured shales, capped by a band of nummulitic limestone, are seen underlying the Siwaliks, which again are similar in character to their representatives to the southward.

Sehâf near Dera Bugti.

The Sehâf, or valley-like plain in which Dera Bugti, the chief and indeed only town of the Bugti tribe, is situated, is a flat extending for a long distance east and west between the nummulitic limestone ranges of Traki to the north and Zen to the south. The average breadth of the plain is 4 to 5 miles. The surface is thickly covered with a sandy deposit, resembling some forms of alluvium, and derived in great measure from the washing down of sand and clay from the neighbouring hills, partly, also, in all probability, from materials transported by wind.

The beds of the Traki range north of the Sehâf are much more disturbed than those of the Zen anticlinal to the south. Against each range there is a fringe of Siwaliks, those to the north of the plain

dipping as a rule at far higher angles than those to the south. South-west of Dera, however, the dips in the Siwaliks are high. East of Dera the Siwaliks north of the valley are nearly or quite vertical, whilst on the south side the dips are very low indeed. Fifteen or sixteen miles to the eastward, near Loti,[1] the Siwaliks terminate, the hard bands of grey and whitish sandstone and white marl forming cliffs, whilst the softer underlying sands and ferruginous beds at the base of the system crop out in the plain.

Conglomerates of Dera valley.

The uppermost Siwalik conglomerates, which attracted Vicary's attention,[2] are well developed throughout the north side of the plain, but are ill seen or wanting to the southward. Altogether the whole thickness of the Siwaliks in the Sehâf from top to bottom, including both the upper and lower sub-divisions, does not appear to be more than 1,500 to 2,000 feet, and this thickness, with the exception of the upper conglomerate, is mainly composed of Lower Siwalik beds, at all events to the south of the valley, where grey sandstones are found throughout.

Fossil vertebrata, &c.

Fossils were only found in the lowest 500 feet or rather more. Mammalian bones were obtained from two localities; a third, not examined, is said to occur near Loti, and it is probable that remains of vertebrata occur throughout the lower portions of the beds. One of the localities observed was Kumbi, about 12 miles west-by-south from Dera, and a place already recorded by Vicary. Here the same *Paludina* and *Unio* bed occurs as at Gandoi (it was noticed in both places by Vicary), and some *Rhinoceros* molars were obtained from it. A few other teeth were also found. The other locality was 7 or 8 miles south-east of Dera. Here, in a sandstone bed, *Mastodon*[3] remains abounded. In other beds of the neighbourhood remains of *Rhinoceros*, *Dinotherium*, a huge *Hyopotamus*, and

[1] By mistake this name has been printed as Lot on the accompanying map.

[2] Q. J. G. S., 1846, Vol. II, p. 262.

[3] Mr. Lydekker informs me that all the teeth brought away belong to *Mastodon angustidens*.

an abundance of crocodile, garial, and tortoise bones and plates were found.[1]

Apparent conformity between Siwaliks and Nummulitics.

There is the same appearance of perfect conformity between nummulitic and Siwalik beds along the north boundary of the Zen limestone ridge, as there is to the south. The only possible exception is near Kumbi, where the uppermost limestone band, that overlying the olive and coffee-coloured shales, becomes much thicker, and it, instead of the lower limestone, forms the surface of the Zen range, precisely as takes place to the southward, near Gandoi. The appearance of unconformity is due to the circumstance that the nummulitics roll about slightly, whilst the Siwaliks crop out in a straight line, apparently unaffected by the minor undulations, along axes differing from that of the main anticlinal, which disturb the nummulitics. But the evidence is very imperfect. North of the valley again, near Sangsila, there is a spot where the Siwaliks do not appear fully to participate in the disturbances of the underlying eocene limestone. The latter forms two great anticlinal rolls at least—one, the terminal portion of the Traki range, the other, to the northward, the great range culminating at Naffusak. The Siwaliks do not run up the intervening valley.[2]

Natural bridge at Sangsila.

A stream, of some size for these almost rainless hills, is fed by a warm spring in the valley north of the Traki range, and enters the plain at Sangsila through a very remarkable natural arch figured in the frontispiece to this paper. The arch is cut through a low ridge of Siwalik conglomerate, which here dips 50° to 60° to the south. There is a pool of water under the arch, which rises about 40 feet above the water, and is perhaps 30 feet wide, and 50 or 60 in length. It is rather curious to conjecture how

[1] Owing to the great difficulties attending the carriage of heavy specimens, very few except teeth and fragments of jaws, were brought away. These localities in the Bugti hills are well worthy of more extended search, the remains being, as has been shown, of much greater geological antiquity than those obtained from the typical Siwalik beds.

[2] Only a hurried visit could be made to the locality, quite insufficient to show whether there was real unconformity.

such an aperture can have originated, but it was probably formed on a curve of the stream, which looks as if it had formerly cut its way through the conglomerate ridge a little further to the westward.

Route from Dera to Harrand.

The route followed left the Sehâf plain close to Dera, and passed by Maráo and Siáh Tank to the great elevated plain known in part as Sham. This plain was crossed from west to east, and from its eastern extremity the track led down the course of the Cháchar stream to the plain of the Deraját, near Harrand.

Hot spring supplying Dera.

Immediately after leaving the plain near Dera, the road to Maráo passed through a narrow gorge in the nummulitics, amongst which rises a warm spring impregnated with sulphuretted hydrogen as usual, though not so strongly as in most cases. This is the spring that supplies Dera Bugti with water for irrigation. Beyond the gorge the path runs along an east and west valley, a synclinal trough of nummulitic limestone. No Siwaliks appear, nor were any observed to the north-east until the low ground was reached on the border of the Deraját.

Plain of Maráo.

The valley traversed opens into the Maráo plain, a flat expanse, resembling alluvium, 8 miles in length by 2 or 3 in breadth, without any outlet. The limestone beds of the surrounding hills dip towards the plain from all sides. The water that falls as rain (not a large amount) doubtless sinks into the limestone, and re-appears as springs. Like some similar plains of smaller size on the Khirthar range in Sind, Maráo is highly fertile, and much wheat is grown without irrigation.

Greatly increased thickness of Nummulitic limestone above shales.

The road from Maráo to Siáh Tank leads through valleys in the nummulitic limestone. The olive and coffee-coloured shales appear in places, but the limestone overlying them must be that forming the hills north of the Sehâf, and several hundred feet thick. This limestone again must be identical with the much thinner band seen in the hills south and south-east of Dera Bugti, and which at Dund

Kushtak is only about 50 feet thick. The question arises whether the great difference in thickness can be due to denudation, or to the bed having been originally much thicker to the northward. The latter is certainly the more probable, for had the limestone bed near Dand Kushtak suffered from denudation, it would in all probability have been removed altogether in places before the deposition of the Siwaliks; and this, so far as could be ascertained, is nowhere the case.

In the olive and coffee-coloured shales near Siáh Tank is a bed of gypsum 10 to 15 feet thick. Siáh Tank is a ravine running through the range of hills that forms the southern border of the Takráo plain, a western prolongation of the Sham. In this ravine is one of the usual warm springs.

Gypsum bed in shales.

From a hill called Kirdári, one of the ranges just mentioned, the geology of the surrounding country can be well seen. The hill and others forming the range south of Takráo plain consist of a lower band of nummulitic limestone underlying the olive and coffee-coloured shales. From beneath this lower limestone band a great thickness of olive shales crops out and forms the extensive plains of Takráo, Sori, and Sham, called collectively on maps the Sham plain.[1]

Hills south of Takráo plain.

The plain is, of course, undulating and destitute of soil. It is very barren, no bushes or trees occurring, except in the hollows near watercourses. The shales of the plain are usually, where weathered, of some shade of olive, but when freshly broken, they are often darker and sometimes slaty. They break into minute flakes, with lustrous, silky surfaces in many cases. In the mode of fracture into small flakes, and in not decomposing readily, with the result that the surface is generally infertile, there is much resemblance between these shales and those of the Talchir subdivision of the Gondwána system. Bands of ferruginous brown sandstone, thick and thin, are intercalated with the shales in places, and in one instance some limestone of the same colour, abounding in *Nummulites leymerici* and

Sham plain.

[1] On the accompanying map the western portion is called Siáh Tank plain.

one or two other species, was found associated with the sandstone. This limestone is identical both in character and position with that seen at the base of Takátu mountain near Quetta.

The watershed between the Sori and Sham plains is a great gravel flat, probably of detrital origin, and the highest part of the tract. It is cut into from each side by the heads of watercourses.

Hills north of Sham plain

The hills to the north of the Sham plain are formed of beds overlying those of the plain itself, precisely like the hills to the southward. The angle of dip varies, the direction is to the northward. The rocks are thin limestone bands intercalated amongst marls and shales, some of the beds being highly fossiliferous and abounding in various Lamellibranchs, Cones, *Nautili*, &c. In the plain north of the range the dip is north at first, then south. Here Nummulites abound, whereas in the lower beds of the Sham plain fossils are rare.

Khúp range.

North of the plain just mentioned is another range running nearly east and west, and known as Khúp. This range consists of an anticlinal of the beds at the base of the lower olive shales, here containing more ferruginous brown sandstone than to the southward.

Hills and plains seen from Khúp range.

From the top of the Khúp range there is a fine view over various plains and ridges beyond. First comes the Phailawar plain, very similar to that of Sham, except that it is not quite so barren. It appears to be formed of the same olive shales. The Siáh Koh to the north of this plain has the appearance of being another anticlinal of lower eocene rocks. Three other ranges seen further to the north-west have much the same appearance. Beyond all these is a higher range, called Jándrán, which looks like nummulitic limestone.[1]

The hills south of the eastern portion of the Sham plain are almost

[1] The continuation of this ridge was examined by Mr. Ball and found to be composed of that rock.

entirely composed of olive shales with a southerly dip of 10° to 15°, and sometimes more. Some shaly limestone occurs in the middle of the shales, and appears to be the same as that forming the surface of Gandahári hill further south, evidently the lower of the two limestone bands seen in the Zen range south of Dera Bugti. In the section south of the Sham plain this lower band cannot be more than 100 feet thick. Some coffee-coloured shale and a band of gypsum occur beneath the limestone. Above it there is no well-marked band of limestone at all; though there is a considerable thickness, 500 feet at least, of olive and coffee-coloured shale, the olive tint passing at times into bluish-green, and at others becoming dark and slaty.

Ranges south of Sham plain.

Upon these eocene beds and forming a great range of hills known as Dab to the north of Gandahári, there is a considerable thickness, 700 feet or more, of some beds quite distinct from any seen in the Bugti hills to the westward. These beds consist of sandstones with subordinate beds of clay, conglomerate, &c.; the most conspicuous strata are earthy brown (greyish-brown) sandstones of great thickness, and with these are associated, especially towards the base, dull reddish-brown sandstones, reddish and yellowish-brown clays, some highly ferruginous bands, and a few layers, hard or soft, stained of a black colour, apparently by manganese. One extraordinary argillaceous sandstone, close to the base, has a strange resemblance to a volcanic rock, being mottled dark green and red; another phase of the same rock apparently might almost be classed as laterite. The beds of the hills composed of these rocks are horizontal, or nearly so, so that the upper portions are formed of the thick brown earthy sandstone; whilst towards the base the variation in colour produced by the thinner bands of highly coloured rock is very remarkable and peculiar; none of the beds are typical of the Siwalik system, and there is a wide difference between them and the Lower Siwaliks that rest on the eocene beds only 15 or 20 miles further east. These peculiar sandstones of the Dab hills are, in all probability, Upper Nari, as

Nari beds near Gandahári hill.

they resemble the strata of that group in Sind in appearance as well as in position.

Changes in strata to eastward.

It is curious to find that the Nari group, wanting throughout the east and west ridges of the Bugti hills, re-appears where the general direction of the ranges turns north and south once more, as in Sind. Unfortunately the oligocene limestone at the base of the Nari does not occur to the north-east. The uppermost eocene limestone, too, appears to have vanished entirely, and the Nari beds rest immediately upon the olive and coffee-coloured shales, although the limestone was well developed only 15 miles further west. Notwithstanding this, there is the same appearance of conformity, although the intercalation of the Nari beds between two systems that were in apparently conformable superposition a few miles to the westward, shows how fallacious these apparent conformities are.

Sulphur locality.

Gandahári hill.

Sulphur is said to be found south of Gandahári hill, in small quantities, amongst whitish beds.[1] Gandahári hill was not examined, but the view of it from a distance shows clearly that it is an anticlinal of eocene limestone, a continuation of that south of Dera Bugti, but much higher.

Chácher Pass.

The bed of the Cháchar[2] stream, along which the road leads from the Sham plain to Harrand, is nearly coincident in position with the change in the strike of the rocks. To the southward, this strike is south-west—north-east, gradually passing into east and west; to the north the axis runs north and south, and the Sulemán range commences. North of the Cháchar Pass is the high ridge called Mári, in places 5,000 feet above the sea. This ridge extends for 20 miles from north to south, and consists of an anticlinal roll of beds inferior in position to the olive shales of the Sham plain,

[1] Probably nummulitic, as are the shales in which the mineral is found further north near Mangrotha.

[2] By mistake printed Cachar on the accompanying map.

and close to the base of the eocene system. South or south-east of the Cháchar is a much smaller hill called Behisto, also an anticlinal ridge, and composed of the same beds as Mári. These beds are chiefly hard, rather coarse brown sandstones, weathering ferruginous brown, some of them purplish, occasionally with red spots on the fresh fracture. With the sandstones is intercalated a band of limestone breccia containing nummulites, the same rock as is found near Quetta.

Behisto hill.

From the top of Behisto, there is a fine view of the tertiary beds extending along the border of the hills to the southward, towards Gandahári. The strata are evidently a continuation of those traversed to the eastward by the Cháchar stream.

Tertiaries seen from Behisto.

In the stream bed between Mári and Behisto, the shales and sandstones are bent into a synclinal, turned on end, hardened and changed into the peculiar phase seen west of Quetta and in Makrán [1] The hardening and alteration of these beds is probably connected with the change of strike.

Alteration of rocks in Cháchar stream.

Further down the Cháchar, after passing the end of Behisto, olive shales come in above the sandstones, at first with varying angles of dip, subsequently dipping about 45° to east or east-by-south. These shales here form the whole eocene system, with the exception of the sandstones at the base. Nowhere throughout the system is there a band of limestone more than 20 feet thick. This remarkable absence of nummulitic limestone continues for at least 50 miles to the northward, along the west flank of the Sulemán range.

Eocene beds in Cháchar.

A few thin bands of limestone do, however, occur here and there in the Cháchar section, and the most conspicuous of them is probably a continuation of the band forming the surface of Gandahári hill, and of part of the Zen range; but the thickness in the Cháchar Pass is considerably less than to the south-west. This limestone band forms the crest of a low ridge running nearly north and south, and seen for many

[1] Said by Mr. Griesbach, as already mentioned, to resemble the "Flysch" of the Alps.

miles to the southward from the top of Behisto. The ridge is rendered conspicuous by the occurrence, just beneath the limestone, of two or three beds of white gypsum, the thickest about 7 feet thick. Above this limestone there is, as to the south-west, no great thickness of shales before the top of the eocene is reached. There is again, as near Gandahári, no limestone above these shales.

Sandstone blocks in tributary of Cháchar.

Just above a spot called Toba, close to the place where the ridge formed by the limestone and gypsum beds crosses the Cháchar, a stream coming from the flanks of Mári to the westward brings down large masses of hard white sandstone, sometimes speckled with brown, together with some fragments of a fine grained sea-green sandstone, also very hard. A few fragments of the last were also seen in other tributaries. The white sandstone is evidently the same as that seen in the Kaha stream further north, and referred to the cretaceous system, and the ravine from which the fragments are derived must evidently cut more deeply into the beds below the eocene than the Cháchar stream itself does.

Gravel slope.

West of Toba all the ground from the foot of Mári to the nummulitic ridge with gypsum beds consists of a great plain of gravel sloping down from the main range to the westward. Some of the fragments are subangular, others rolled. All appear to be derived from the brown sandstones of the lower eocene, and many are covered with a ferruginous glaze.

Nari beds in Cháchar Pass.

It has already been mentioned that the top of the eocene system in the Cháchar section is not far—a few hundred feet at the most—above the ridge of nummulitic limestone and gypsum. The next beds above the eocene shales are the same as those already mentioned as occurring north of Gandahári hill and as belonging, in all probability, to the Nari system. The rocks on the Cháchar are precisely similar to those near Gandahári; earthy brown sandstones above in very thick beds, with some intercalations of sand and sandy clays and, towards the base, deeply coloured sandy and argillaceous beds, ferruginous, brown and black predominating. No trace

of oligocene limestone can be detected. The dip in the Nari beds is lower than in the eocene, and, except at the base, does not exceed 35°.

Lower Siwaliks.

The thickness of the Nari beds is not very great. They are succeeded, to all appearance quite conformably, by Lower Siwalik strata, grey sandstones, Indian red clays and conglomeratic beds, with the included fragments entirely composed of marls, sandstones, and clays, similar to those of the associated strata. No trace of Gáj beds could be found. The dip gradually decreases to the eastward; it is 30° towards the base of the Lower Siwaliks, but only 10° to 15° two or three miles further east.

Upper Siwaliks.

Conglomerates with nummulitic pebbles, characteristic of the Upper Siwalik beds, appear in the bed of the Cháchar about half way between the places where the Karagáni and the Kumbi, two minor affluents, enter that stream. Towards the plain of the Deraját the dips do not exceed 10°. Either the massive uppermost Siwalik conglomerate is not well developed here, or it may be concealed beneath the alluvium of the Deraját plain; it re-appears a few miles further north.

CHAPTER IX.

NOTES ON THE SOUTHERN PORTION OF THE SULEMÁN RANGE FROM HARRAND TO MANGROTHA.

Section in Kaha Stream.

To the west of Harrand an excellent section of the rocks composing the Sulemán range is exposed in the Kaha stream, which cuts a deep gorge from side to side of the chain between two high masses, one called Mári, to the south, and the other, known as Dragal, to the north.

Siwalik conglomerate.

Marching to the westward from Harrand, a well marked ridge of the usual coarse, uppermost Siwalik conglomerate is seen along the border of the alluvial plain. The Siwalik rock dips eastward at 45° to 50°; outside of it (between it and

the alluvial plain), and resting unconformably on its upturned edges, are the usual post-tertiary gravels, themselves cemented into a conglomerate.

The thickness of the Upper Siwaliks is not great. Just beneath the conglomerates of the outer ridge light brown sandstones with conglomeratic bands prevail, but some grey sandstones are intermixed with them, and in the conglomerates, together with pebbles of nummulitic limestone, are fragments of soft sandstone. The line between Upper and Lower Siwaliks, here as elsewhere, is drawn where the nummulitic pebbles, characteristic of the former, first make their appearance, but the division is somewhat arbitrary, the two stages passing into each other. The Lower Siwaliks are thicker than the Upper, and consist, as usual, of grey sandstones, of the typical conglomeratic beds, containing soft sandstone and clay fragments, and of a few interstratifications of red sandy clays.

Lower Siwaliks.

The change from the Lower Siwalik to the Nari group is more abrupt, though no unconformity can be traced. Instead of grey sandstone, massive brown sandstone crops out, with grits or fine conglomerates, light brown or whitish in colour, containing subangular fragments of quartz. Brown and reddish argillaceous beds are also interstratified. There are, as in the Lower Siwaliks, some conglomeratic beds with sandstone and marl fragments. Towards the base the usual highly coloured beds occur, as on the Cháchar stream and near Gandahári hill.

Nari group.

To the Nari beds succeed the olive beds of the eocene, precisely as on the Cháchar. The thin band of limestone, with the conspicuous beds of gypsum beneath it, appears here also. The shales occupy the valley of the stream for about 3 miles; they extend to the foot of the main range, and have scarcely any limestone interstratified. The dip to the eastward gradually diminishes from 50° to about 20°. At the main range the hard brown sandstones to which its existence is evidently in great measure due, and of which its surface is largely composed, crop out from beneath the olive shales, the two being interstratified to some extent, and occasional beds

Eocene beds.

of shale being found in the sandstones. Where these hard sandstones crop out, the gorge cut by the Kaha stream commences, and for a considerable distance the river traverses the same beds, which are clearly the same as those seen at the base of the eocene on the Chachar.

Whitish sandstone probably cretaceous.

The next strata in descending order consist of hard whitish coarse sandstone and grits, well bedded, and dipping about 15° to the eastward. These are doubtless the rocks of which fragments are seen in the tributary that joins the Chachar near Toba. Some are pale greenish or bluish-green in colour; others purplish or speckled with purple or brown, but the majority are very pale coloured, almost white. A few infrequent bands of shale occur, mostly dark coloured. These beds appear to be unfossiliferous. As stated in Chapter III, they are probably of cretaceous age.

Hot springs.

Several small hot springs issue, either in the bed of the stream or just above it, amongst these sandstones. All emit sulphuretted hydrogen, like the springs in the nummulitic limestone of Sind and Baluchistan.

Cretaceous limestone.

After traversing a thickness of probably not less than 1,500 feet of the whitish sandstones, limestones are reached, very dark in colour, and rather sandy or shaly. They contain very indistinct fossils, chiefly *Foraminifera*, amongst which no Nummulites can be detected. These limestones gradually pass downwards into calcareous shales, dark grey in colour, often very nodular. Fossils are rare, but two species of *Exogyra* and an *Inoceramus* were found. The fossils are cretaceous.

All beds conformable.

No unconformity could be detected between any of the different groups exposed in the section from Upper Siwalik to the cretaceous limestone shales.

Anticlinal.

The limestone shales are the lowest beds seen. Further westward all the beds roll over and dip west. The surface of the Mári and Dragal hills is formed chiefly of lower eocene sandstone on both slopes; in the Gargandáva valley, to the west of the range, it is probable that only eocene rocks occur.

Section of the rocks seen in the Kaha stream.

a, b, c, cretaceous (*a*, limestone shale; *b*, limestone; *c*, white sandstone); *d*, eocene; *e*, Nari; *f*, Lower Siwalik; *g*, Upper Siwalik; *h*, post-tertiary.

The accompanying section shows the general disposition of the rocks. A rough estimate of the thickness of each group is given below :—

Thickness of beds.

		feet.	
Upper Siwaliks	.	2,000 to 2,500	(top not seen).
Lower do.	.	5,000	
Nari		2,000	
Eocene	.	8,000 to 10,000	(Of this thickness the bottom sandstones comprise least 1,000.)
Cretaceous, white sandstone		1,500	
„ limestone and limestone shale		1,000	(base not seen).

Gathi Nadi.

At Gathi Nadi, 5 or 6 miles north of the Kaha, the outer range is entirely composed of the usual coarse conglomerate. Immediately beneath, grey Lower Siwaliks crop out, dipping eastward about 50°.

Khosra Nadi section.

The Khosra (or Kosah) stream is 6 or 7 miles further north. South of it is seen an instance of the tendency, common in Sind on the edge of the Khirthar range, but rarely observed in the Derajat, for the dip of the Upper Siwalik conglomerates to become lower towards the top, and for them to pass into the gravels of the slope along the base of the hills. But little conglomerate is seen and the Lower Siwaliks appear but a short distance inside the hills.

The section below the conglomerate is very similar to that seen on the Kaha

stream. The Nari beds contain in their upper strata a much larger quantity than usual of reddish or orange brown, deep ferruginous red and yellow clays. There are the usual richly coloured beds at the base. The eocene olive shales, which succeed, present no unusual peculiarity. After passing over them for half a mile, a low ridge is met with, formed, as in the Kaha and Chúchar sections, of the outcrop of some beds of limestone overlying gypsum. The latter here is 25 to 30 feet thick. Below are more olive shales, and interstratified with them in places are a few bands, each 2 to 3 feet thick, of nodular limestone. The dip becomes gradually lower towards the base of the main range, where brown sandstones appear as usual.

Clay used for washing hair

Amongst the upper olive shales in the Khosra are some clays used by the people of the country for washing their hair, and considerable quantities are dug for carriage to local bazaars, as in Sind.

Rocks in the upper Khosra and feeders.

The section was not examined beyond the outcrop of the lower nummulitic strata, but from a hill a good view was obtained of the upper portion of the Kála Khosra, the principal southern branch. The white sandstone below the eocene is cut into, but no lower bed appears to be exposed.

From a hill on the outer ridge of Siwalik conglomerate, between the Khosra and Choti streams, the ravines cut by the northern branches of the Khosra into the flank of the main Sulemán range are well seen. The deepest gorge is that of the northernmost tributary, called Bagar Khosra; in this some grey beds are exposed, doubtless cretaceous limestone. The stream in question is called Jingar on the atlas map.

Conglomerate unconformable to Upper Siwaliks.

The conglomerate of the outer range north of the Kura stream (about 8 miles north of the Khosra) dips at a low angle to the eastward, and is about 300 feet thick. It rests unconformably at one place on Upper Siwalik sandstone, the conglomerate dipping 15°, the sandstone 30°. The conglomerate appears to pass up into the gravels of the slope,

but is probably uppermost Siwalik, and there is evidently a slight break in continuity between it and the Upper Siwaliks beneath.

Siwalik sandstone on Kura stream.

Below the Upper Siwaliks on the Kura stream are some whitish sandstones, with conglomeratic bands. These beds are intermediate both in character and position between Upper and Lower Siwaliks.

Siwalik anticlinal north of Choti Bala.

A low ridge running for about 12 miles from north to south rises from the alluvial plain to the eastward of the hill country, commencing to the southward at the small town of Choti Bala,[1] on the Choti stream.[2] This ridge is a low anticlinal of Upper Siwalik beds. The dips are very low, not more than 1° to 2° near Choti Bala, but to the northward considerably higher, being as much as 10° near Sakhi Sarwar.

Road to Fort Munro.

The road to Fort Munro, a sanitarium on the Sulemán range, passes by Choti Bala, and traverses the outer ridge, formed of the uppermost Siwalik conglomerate, by the gorge of the Choti river. The Lower Siwaliks, Nari and Eocene beds above the brown sandstones, are ill seen on this road, which passes over a gravel flat, or low slope. There appear remains of two such slopes in this neighbourhood; one higher, and probably more ancient, south of the Choti stream; the other, to the northward, lower and traversed by the road. The Nari group appears to increase in thickness to the northward. A thin band of shaly limestone occurs above that overlying the thick gypsum band, whilst below the latter are some beds of impure limestone, abounding in casts of *Lamellibranchiata* and some *Gasteropoda*.

Section in Choti stream.

The gorge of the Choti stream, which cuts a deep ravine into the heart of the main Sulemán range, lies south of the spur up which the road to Fort Munro passes. Close to the base of the main range, the eocene olive shales occur in the stream, dipping 70° to 80°, but the dip soon becomes lower, and

[1] Not marked in the accompanying map, and in the atlas sheet called Grave Bulesl.

[2] The Nongarh, north of the accompanying map, is a continuation of part of this stream to the eastward.

about a quarter of a mile further west, where the white sandstone crops out from below the base of the eocene, the dip is only 30°. Near the bottom of the olive shales, there is much green limestone, then come the purple and brown sandstones of the lower eocene, then the (cretaceous?) white sandstones. The latter appear scarcely so thick here as on the Kaha, 25 miles further south-south-east, although they form huge cliffs. The cretaceous limestones crop out in due course, dipping east at about 20°. There is an appearance of local unconformity between the limestones and the white sandstones, but it is probably only oblique lamination, for the limestone and sandstone are interstratified.

Eocene.

Cretaceous.

The upper portion of the limestone, as on the Kaha, consists of dark-grey beds, well bedded, and full of obscure fossils. The shaly lower beds are by no means very fossiliferous, but besides the ribbed Inocerami, similar to those in the Kaha section, a coiled cephalopod with the whorls transversely ribbed was found, several poorly preserved specimens being seen, although but few could be brought away, and those only in fragments. The form belongs to the *Ammonitidæ*, but appears to be allied to *Hamites* or some similar genus rather than to true *Ammonites*. Two species of *Inoceramus* probably occur, one with the ribs broad, very regular and concentric, the other with them narrower, and less regular. Some fragments of stems and indistinct remains of leaves were also noticed.

Cretaceous limestone

Fossils.

Perhaps lower beds are exposed in the Choti section than on the Kaha. The lowest seen on the first named are less distinctly stratified, and are cut up by joints in all directions. The shales are bluish-grey on the exposed surfaces, dark-grey on fresh fractures.

Lowest beds seen.

Above the stream are cliffs fully 3,000 feet high. The upper 300 or 400 feet are composed of lower eocene sandstones, the remaining 2,500 feet or rather more being

Thickness.

about half white sandstone and half limestone. In the stream bed a small hot spring occurs as usual.

Ascent from Zerádán to Fort Munro.

The road to Fort Munro commences to ascend the main range close to Zerádán, where there is a small bungalow. Near the bungalow, as in the Choti stream to the southward, olive shales are seen, together with a few bands of nodular limestone, both dipping 60° to 70°. A short distance up the slope, there are large quantities of the peculiar lower eocene nummulitic limestone breccia, with *Nummulites* and *Alveolinæ*. Some of the masses appear to be in place, and if so, the bed must be nearly at the top of the lower eocene brown sandstones with which it is intercalated.

The dip gradually diminishes as the hill is ascended, the surface nearly corresponding in slope with the dip of the beds. About 3,000 feet above Zerádán a limestone band containing oysters is seen interstratified in the lower eocene. The same bed occurs in the Kaha section, where fragments are found in the stream bed. A little higher up, the white cretaceous sandstone crops out from below the eocene and forms all the surface of the spur. These beds are cut through, and the underlying limestone exposed in the gorge of the Choti Nadi to the southward as already mentioned, but not in the ravine immediately north of the road. In another deep gorge however, that of the Siri stream, further to the northward, and seen from Fort Munro, the limestone is cut into.

Limestone breccia.

The top of the Sulemán range is flat, and here lower eocene beds again come in. A little knoll, apparently the highest in the neighbourhood, to the south of the road, is capped by the limestone breccia. West of this the dip is westward, and the same breccia re-appears on the road to the fort, and again on a little hill, west of that on which the bungalows stand, the bed apparently dipping somewhat irregularly. Judging by the cliffs at the head of the Choti the limestone breccia, which is, as already shown, near the top of the brown sandstones, is only 300 or 400 feet above the top of the whitish cretaceous sandstones, but there may be some faulting, for elsewhere

the whole thickness of the brown sandstone appears to be more nearly 1,000 feet than 500.

View from Fort Munro.

The hill on which the bungalows of Fort Munro are built is on the western side of the Suleimán range, and commands a wide view over the country to the westward. All the ranges as far as the Jándrán appear to be eocene, and so doubtless are the intervening plains.[1] The western slopes of the Suleimán appear also, near this, to be composed of lower eocene rocks. The portion of the range on which the hard whitish cretaceous sandstones are exposed lies just east of the crest, and extends south, as shown on the accompanying map, apparently without interruption as far as the Kála Khosra stream, and north to beyond Ek Bhai mountain, where this sandstone forms a precipice to the west of the highest peak. To the west of this precipice dark lower eocene beds appear to come in, perhaps, as Mr. Ball suggests, faulted against the white sandstone.

Section on Siri stream.

The Siri stream is a watercourse of some size that traverses the hill country 6 or 7 miles north of the road to Fort Munro, and enters the alluvial plain west of Sakhi Sarwar, a shrine of wide reputation amongst both Mussalmans and Hindus. Along the course of the Siri a road was made by Major Sandeman (now Sir R. Sandeman) to the Luni Pathan country.[2] The road is now abandoned and nearly destroyed by rain and streams.

This route enters the hill country, after skirting the hills west of Sakhi Sarwar for some miles, by a gorge between cliffs 500 to 600 feet high, formed of the uppermost Siwalik conglomerate, here horizontal. West of the ridge formed by these beds there is a sudden change in the dip, and the Upper Siwaliks come in dipping at 30° to 40°. As already mentioned in Chapter III of the present report, there may be some unconformity, but the appearance is chiefly due to disturbance.

[1] This is in accordance with Mr. Ball's account (Rec. G. S. I., Vol. VII, p. 146) of the section traversed a little further north. (See Chapter I.)

[2] This was the road traversed by Mr. Ball in 1874 and described by him in the seventh volume of the Rec. G. S. I., p. 145.

The Lower Siwaliks come in as usual below the Upper, dipping at about 45°. Close to their base is a bed abounding in shells and resembling the shell bed at Gandoi and Kumbi in the Bugti hills. The shells, however, are in this case so badly preserved that it is very difficult to identify them. The commonest is a bivalve very like *Unio cardiiformis* of the Bugti hills, but still more like a *Cardium* in appearance; another looks like *U. vicaryi* of the same bed, and a univalve was seen, apparently a *Paludina*. Some fragments of bones were found, but nothing determinable.

Shells in Lower Siwaliks.

Just beneath is a highly ferruginous bed, one of the usual conglomerates of rolled clay balls, but saturated with iron peroxide, which has segregated in nodules of irregular form, often hollow. Only a few bone fragments, none of which could be identified, were observed in this.

The Nari beds form a steep ridge, the strata dipping at 50°. They come in just below those last noticed. The ridge can be seen for a long distance to the northwards and is higher than any other in the neighbourhood.

Nari group.

The eocene or nummulitic beds are the same as usual, only subordinate thin bands of limestone occurring.

Eocene.

As far north as Sakhi Sarwar, the lower ridges intervening between the main Suleimán range and the alluvial plain of the Indus are formed by the outcrops of the various tertiary beds dipping eastward, as shown in the section of the Kaha stream. But north of Sakhi Sarwar there is a double roll of the strata, a synclinal near the main range, followed by an anticlinal further east, and the fringe of lower ranges is much wider, all the beds down to the eocene inclusive being exposed in the anticlinal.

Double roll of beds north of Sakhi Sarwar.

Ascending the stream that issues from the hills at Sakhi Sarwar, the Lower Siwaliks crop out just inside the first range. The boundary is unusually well seen, and there is no unconformity. North of Sakhi Sarwar, the dip of the uppermost conglomerate in the hills bordering the plain is very high.

Siwaliks near Sakhi Sarwar.

Sakhi Sarwar lies nearly west of Dera Gházi Khán. North of this but one double traverse of the hill country was made from Vadúr (Wuddore) by the Vadúr Pass to the foot of Saronk and back from the Sáonra (Sounhra) Pass by the Sangarh track to Mangrotha.[1]

Traverse of hills further north.

At the entrance to the Vadúr Pass near Vadúr the uppermost Siwalik conglomerate is not seen; the Upper Siwaliks are vertical, striking N. 15° E. They only continue a very short distance, certainly not half a mile, before the whitish intermediate sandstone appears, followed by the grey sandstone of the Lower Siwaliks. All the beds are vertical or dip at a very high angle.

Vadúr Pass.

Quite at the base of the Lower Siwaliks, in a bed similar to that seen in the Siri section, two species of *Unio* occur, one of them ribbed and probably identical with *U. cardiiformis* of the Bugti hills. Associated with these are a *Cerithium*, a *Natica* and a *Cyrena*-like shell. This bed may be estuarine, and possibly indicates the northern extension of the marine Gáj or miocene area of Sind.

Marine or estuarine shells in Siwaliks.

The Nari group appears thin and only continues about 200 yards; it cannot therefore be much more than 500 or 600 feet thick. Beneath it, in the olive eocene shales, there is some brown limestone, like the oligocene Nari limestone of Sind, but evidently of eocene and not of oligocene age, for it contains *Orbitoides dispansus* and a nummulite that looks like a large variety of *N. biarritzensis* or *N. beaumonti*.

Nari.

Eocene limestone.

The nummulitic beds form the axis of the anticlinal; they soon roll over and become horizontal. They continue thus for about 4 miles, then they dip westward. Only a few hundred feet of shales are seen in the Vadúr stream beneath

Anticlinal axis.

[1] In consequence of illness, which finally obliged me to leave the field, the observations were few and in-

the limestone bands associated with gypsum, which are as conspicuous here as further south.

Nari beds west of anticlinal.

West of the anticlinal, the Nari beds appear better developed than to the eastward, and form a well-marked ridge, higher than any other in the neighbourhood, as they do on the Siri stream. They dip about 35° to west.

Siwaliks.

The Lower Siwaliks then appear and continue for a long distance. They dip at 50° when they first come in, but the dip diminishes to the westward. No shell bed is here seen at their base. The Upper Siwaliks are almost horizontal; they form part of an open plain, covered in general by gravel, and extending nearly to the foot of the main range. It is far from easy here to distinguish between them and the Lower Siwaliks. Pebbles of nummulitic and *Alveolina* limestone occur in grey sandstone, which must be classed as Upper Siwalik, although such grey sandstones, in this country, generally belong to the lower sub-division. It is very possible that further north the two sub-divisions of the Siwaliks cease to be recognisable, and become undistinguishable as they are in Sind.

Nari beds near Gurk.

Nari sandstone is well seen near a place called Gurk (Guruk). It dips 30° to the eastward and contains an unusually hard band, as hard as the white cretaceous sandstone.

Eocene.

In the eocene beds near the base of Saronk, there is a considerable increase in the quantity of limestone, compared with the same beds further south. The limestone above the gypsum beds, which continue to occur, is thicker, and there are many more bands intercalated in the shales below. In the Sáonra or Sangarh stream a limestone bed about 200 to 300 feet thick is cut through. This bed forms a distinct and well-marked ridge, continuing for a long distance to the north, and known as the "White range." Through this range there are said to be very few passes, but a good road leads between it and the main range to the Vehowah stream. It is worthy of notice that the

Nummulitic limestone.

band of nummulitic limestone here appearing is in the middle of the system, having shales both above and below it, and is, not like the Khirthar, at the top of the eocene.

Beds of main Suleimán range.

Owing to circumstances the high range of the Sulemán was not visited and the mapping of the beds below the eocene is in great part a matter of conjecture. The brown lower eocene sandstones can be seen from a distance running up the slopes, and the greater portion of the hills appear to consist of the hard white sandstone. In the Lurkán stream, running from the south side of the lofty peak Ek Bhai, and in the Rúkán coming from the north, between Ek Bhai and Mawaiki, fragments of grey limestone and limestone shale, apparently derived from the cretaceous beds, abound. But these fragments are so numerous in the gravels of the surrounding plain that the occurrence of some in the stream bed really proves nothing. Moreover, calcareous grey shale and grey limestone occur in eocene beds a little further north, near the base of Saronk, and fragments derived from them are indistinguishable from those of the cretaceous rocks. Still there is good reason to believe that the cretaceous limestone is exposed in the streams named, in consequence of the depth to which their channels are cut.

On the crest of the Sulemán behind Mawaiki, lower eocene sandstones appear to occur, as well as above the deep gorge of the Rúkán stream between Mawaiki and Ek Bhai.

North of Saronk, the lower eocene strata appear to cover up the older beds, and to form the surface of the range, and in the Saonra Pass, a broad valley that traverses the main range from east to west, no beds are exposed lower than the hard sandstones at the base of the eocene. The pass, in fact, is a low synclinal (or to be more exact, a spot where the anticlinal forming the main range dies out for a short distance), the rock at the surface, throughout a considerable area, being the same massive band of coarse sandstone. To the northward, the beds rise again and form a hill known as Mári, and the Sulemán anticlinal doubtless reappears.

Section on Sangarh stream.

Going down the Sangarh stream, which runs north-east, diagonally to the strike of the beds, the same section is seen as was observed on the Vadúr. Above the eocene system, the Nari beds are well developed and contain much red clay.[1] They dip about 30° to 40°. Again here, as in the Vadúr stream, it is difficult to distinguish between Upper and Lower Siwaliks.

The rocks turn up again about 15 miles from the hills, and are repeated twice, precisely as in the Vadúr stream, by an anticlinal, in which all the tertiary beds crop out down to the upper eocenes. To the south of the stream, the latter, probably in consequence of an increase in the thickness of the limestone, form hills of considerable height.

Sulphur mines.

Sulphur is extracted from eocene beds in two localities near the banks of the Sangarh. One of these places is west of the anticlinal and is callad Swaidko, the other called Galki is only 6 or 7 miles from Mangrotha. In each case, the ore, a mixture of sulphur and gypsum, is brought from the eocene beds at some distance. The mines were not visited.

Siwaliks near Mangrotha.

East of the anticlinal, on the edge of the alluvial plain, no Upper Siwaliks are seen; the ascending section terminates with the Lower Siwaliks. The beds above the eocene dip at high angles.

[1] This shows a resemblance to the typical Murree beds.

PART III.

CHAPTER X.

ECONOMIC GEOLOGY.

Deficiency of useful minerals.

It has become the practice in these memoirs to append a chapter on economic geology, although, in cases like the present, when scarcely any minerals of value are known to occur, and when the examination of the country has been too superficial and partial to afford trustworthy evidence as to the probability of any being found, such a chapter is little more than a confession of ignorance. The few remarks here appended must be considered rather as references to the previous chapters, than as an account of the useful mineral products.

Coal of Bolán and Harnai routes.

Coal.—The only localities at which coal has been observed are Mach in the Bolán Pass and Sháhrág on the Harnai route from Quetta to Sibi. In both places the coal is eocene. A full account of the seams, so far as they have been examined, of the quality of the coal, and of the conditions under which it occurs, was published in the Records of the Geological Survey of India for 1882.[1] The geological features of the localities are described in Chapters IV and VI of the present report. As far as is hitherto known, the seams are much too thin to be profitably mined on a large scale, and there is great doubt as to their being constant in thickness over any considerable area. The quality appears to be sufficiently good for most purposes.

Coal of Luni Pathan country.

The coal of Chamarlang, west of the Sulemán range, and beyond the area examined, was examined by Mr. Ball as already noticed in Chapter I, and appears to resemble that of Mach and Sháhrág in character and geological position.

In connexion with coal the reported petroleum locality of the Mari

[1] Vol. XV, Pt. 3, p. 149.

hills may be mentioned. It is at a distance of four or five days' march to the eastward of Gandkhindaf on the Harnai route to Quetta, and, as stated in the first chapter, want of time prevented a visit to the spot. From the accounts received, however, it is probable that the quantity of petroleum is very small, as it is in some places in the Punjab, and especially one close to Ráwalpindi.

Petroleum of Mari Hills.

Sulphur.—The occurrence of sulphur at several localities just beyond the Sind and Punjab frontier is well known, and some account of the mineral was given by Mr. Ball in the third volume of the Manual of the Geology of India.[1] The most important mines are west of Bágh in Kachhi, and the sulphur is extracted near that town. As already mentioned, time did not permit of a visit to the locality. Another locality is that mentioned in the last chapter, in the Sangarh Pass[2] west of Mangrotha. Here,[3] as already mentioned, the mineral brought to the place where the sulphur is extracted is a mixture of that substance with gypsum.[4]

Sulphur localities.

Bágh

Near Mangrotha.

It is possible that the sulphur may have been derived from the decomposition of hydro-sulphuric acid; this substance (sulphuretted hydrogen) is always emitted by the warm springs that occur so frequently in the hills of the Sind and Punjab frontier.

Another locality, as already mentioned in Chapter VIII, is said to exist south of Gandahári hill, but it is not worked; other places may also occur; indeed it is not improbable that the mineral is rather widely distributed in the eocene beds.

Near Gandahári hill.

[1] Page 157.

[2] This is, I think, the locality near the Sooree Pass mentioned by Mr. Ball. The Sooree or Shori Pass is nearly 20 miles south of the Sangarh. I was told that no sulphur is worked in the Shori Pass, but both Mr. Ball and I had to trust to native information.

[3] I was greatly disappointed at being unable to visit the places whence the mineral was actually obtained, but I was too unwell at the time to leave the main track.

[4] So far as I could learn by enquiry and could ascertain by the character of the country, the sulphur occurs in eocene beds. I could not find any confirmation of Mr. Ball's suggestion in his first notice that the sulphur is of volcanic origin. No volcanic rocks were observed in the neighbourhood.

Process of extraction.

The process of extraction was seen in the Sangarh Pass at two places, and is of the rudest kind. Two ordinary earthen *garrahs* or *handis* (nearly spherical earthen vessels about 15 to 18 inches in diameter, with a mouth 3 or 4 inches across[1]) are placed vertically mouth to mouth and luted together. The lower *garrah* is sunk in the upper wall or roof of a small furnace or hearth, and in this *garrah* ore is placed. The upper *garrah* is exposed, and when the lower is heated by a fire in the hearth, the sulphur is sublimed, and deposited inside the upper in the form of "flowers of sulphur." This is melted and then cooled again in cakes weighing about a seer (2 lb) each, the cakes being formed by pouring the melted sulphur into a fragment of a broken *garrah*.

Gypsum.—This mineral, as already mentioned, is common in the tertiary rocks. It occurs as thin veins filling cracks in the upper Siwaliks around the Kachhi, and in the rocks which I believe to be of the same age in the Mashalak range west of Quetta. In the latter larger masses of gypsum are said to occur.

Gypsum localities.

At the base of the Lower Siwaliks, in the hills south-east of Pulaj, and north-by-east of Shahpúr, at the western extremity of the Bugti hills, some very beautiful white gypsum, or alabaster, was found in irregular masses, some of them as much as a foot in diameter; some of the masses are perfectly pure white in colour, and quite as well adapted for ornamental purposes as the precisely similar stone that is carved into statuettes and vases at Pisa and other places in Italy.

Gypsum, too, occurs in beds of from 5 to 10 feet in thickness in the eocene beds of the Bugti hills and the eastern flank of the Suleimán range.

The use of plaster made from gypsum, instead of mortar from lime, for building is common in Persia, and I believe in many other parts of Central Asia, as in Afghanistan, where the rainfall is not heavy. Some use has been made of similar plaster at Quetta, the gypsum being

[1] The measurements are given from memory, and may not be exact.

obtained from the neighbourhood of the Ghäziaband Pass on the Mashalak range.

Building stones.—The limestones of the cretaceous and eocene systems generally furnish excellent building stone. Some of the upper tertiary sandstones are also well adapted for building purposes, but they are often liable to crumble in exposure. At Quetta the dark cretaceous limestone is used for building.

APPENDIX.

DESCRIPTION OF FRESH-WATER SHELLS FROM LOWER SIWALIK BEDS OF THE BUGTI HILLS

The following species were briefly noticed in Part I, Chapter III. They are very curious and interesting forms, and, although I have rarely attempted to describe fossils, I have been induced to undertake the task in the present instance, because I have some acquaintance with the living species of the same genera now inhabiting India and the neighbouring countries, and because of the peculiar interest attaching to fossil land and fresh-water Mollusca in general :—

1. MELANIA PSEUDEPISCOPALIS, sp. nov., Pl. 1, figs. 1, 2.

Testa pro genere magna, solida, breviter turrita, fere pyramidata. Spira imperfecta; anfr. superst. 3½ convexi, sensim accrescentes, costis verticalibus fortibus distantibus, in anfr. ultimo superne juxta suturam atque infra medium evanescentibus ornati, et lineis spiralibus elevatis filiformibus distantibus tuberculoso decussati. Anfr. ultimus basi liris spiralibus confertioribus 4—5 ornatus. Apertura ? Long. 1·92; diam. 1 1 poll. angl. Apert. long. circum 1.

Shell large for the genus, thick, moderately turreted, not elongate, but almost pyramidal. Spire imperfect, about 3½ whorls remaining, which are well rounded, and increase in size regularly. They are ornamented with vertical ribs and raised spiral lines; the ribs are far apart from each other, and appear, so far as can be made out, to vanish above near the sutures, and below the middle of the last whorl; they are nodose where crossed by the spiral lines, which are distant from each other, except around the base of the last whorl, where they are rather closer together. So far as can be judged, there must be on the last whorl 5 or 6 distant raised spiral lines round the upper and middle portion, and 4 or 5, closer together, round the base. The form of the aperture cannot be ascertained, but was probably sub-rhomboidal, as in the recent *M. variabilis*.

Melania pseudepiscopalis belongs, so far as can be judged from the single specimen procured, in which the aperture is not preserved, to the sub-genus *Melanoides*, Oliv. and is most nearly allied to *M. variabilis*, Benn., *M. episcopalis*, Lea, and *M. sumatrensis*, Brot. It is a difficult question how far these species are really separable from each other, and from numerous closely allied forms that have received names from various conchologists. The form that comes nearest to the type now described, of all that I have been able to compare, is one figured in Hanley and Theobald's Conchologia Indica, Pl. LXXII, fig. 5, under the name *M. episcopalis*, Lea. This specimen, which is from North Cachar, differs considerably from the other

forms referred to the same species in the work mentioned.[1] A specimen from Assam in the British Museum, referred to *M. variabilis*, is also very nearly allied to the fossil.[2]

Amongst the figures in Brot's admirable monograph of the *Melaniidæ*[3] the three forms most nearly allied, so far as sculpture is concerned, are Pl. 11, fig. 2, *M. julieni*, Desh., from Tonquin, Pl. 12, fig. 1a, *M. episcopalis*, Lea, from Malacca, and Pl. 13, fig. 1a, *M. sumatrensis*, Brot, from Sumatra. All of these forms, however, have higher and more turreted spires, and the vertical (transverse) ribs in *M. pseudepiscopalis* are more distant. The spiral lines also are differently arranged. The present form, therefore, may receive nominal distinction.[4] No known fossil species appears to be very nearly allied.

The similarity between the present form and the species mentioned of the subgeneric section *Melanoïdes* is so well marked that there can be very little doubt as to the affinities of *M. pseudepiscopalis*. The living species of *Melania* belonging to the same section are found along the base of the Himalayas, as far west as the Jumna, and perhaps rather further; they occur throughout a considerable portion of the Gangetic plain, and in Orissa, and they abound in Burmah, the Malay countries, Siam, and the islands of the Malay Archipelago, &c. A species has been found in Malabar, and the type is probably represented in Ceylon, but it is wanting throughout the greater part of the Indian peninsula, and is quite unknown in Sind, the Punjab and all Central India.

Two views of the same specimen are given in figures 1 and 2 of Plate 1.

2. Melania gradata, sp. nov., Pl. 1, figs. 3—5.

Testa gradato-turrita, solida, crassa, lævigata. Spirâ vix erosa. Anfr. 6. gradatim accrescentes, haud procul a suturâ forte atque prominenter angulati, infra angulum fere cylindracei, lateribus verticalibus planisque, antice concaviusculis; ultimus parum major, infra angulum concavus, subtus convexus. Apertura fere ovata, postice angulata; margine externo postice retro sinuato, antice arcuato. Long. 1·05; diam. 0·5; ap. long. circum. 0·45 poll. angl.

Var. major, minus elata, ovato-turrita. Long. 1·25; diam. circum. 0·75 poll. angl.

Shell turreted, thick, smooth. The spire is high, scarcely eroded at the apex, and composed of six whorls in one or two specimens, five in others, regularly increasing in size by steps, sharply and prominently angulate just below the suture, and nearly cylindrical below the angulation, the sides being flat and vertical in the upper whorls, slightly concave in the lower, especially in the last whorl, which is prominently but bluntly angulate near the suture, then hollow at the side and convex towards the base. Aperture ovate, not preserved entire in any specimen, but raised lines of growth

[1] By Brot (Mart. Chemn. Conch. Cab., Melaniacea, 1874, p. 89.) these forms are referred to *M. spinata*, Godwin-Austen, but the particular figure 5 of Pl. 73 above noticed is not quoted in Brot's synonymy.

[2] I am indebted to Mr. E. Smith, the Assistant Keeper, for this comparison. He also pointed out to me the resemblance of the fossil to a form of *M. asperata*, Lamarck, from the Philippine Islands.

[3] See preceding note.

[4] It is rather a question of convenience than fact, whether closely allied forms of fresh-water molluscs shall be classed as "species" or "varieties."

showing the form of the lip when the shell was not quite mature are preserved in a few cases, and show that the posterior or upper part of the outer margin was sinuate or curved back for some distance below the suture, whilst the anterior or lower portion was arcuate or curved forward; the base was probably curved back, perhaps sub-canaliculate.

Var. major, Pl. I, fig. 4. Two specimens, rather larger than the rest, differ in having the spire less raised. I think, however, that there is not sufficient evidence to class these specimens in a different species. One of them has spiral sub-distant impressed lines round the base of the last whorl. This may show that it is really a different species, but there are similar lines, though fewer, on one specimen of the smaller form. No such lines, however, occur on those specimens of which the surface is best preserved.

I am unable to find any species of *Melania*, living or fossil, allied to the peculiar type here described. In general form there is some resemblance to the sub-genus *Plotia*,[1] comprising *M. scabra* and its allies, some of which have the whorls angulate below the suture, but the form of the aperture is different. The group *Tiara*, in which the angulation is more marked and the whorls usually smooth, has a much larger last whorl, and a nonsinuate external margin to the peristome. In both these groups the angulation of the whorl is ornamented with spines, and the same may originally have been the case with *M. gradata*. The present species may be allied to the section *Tiaropsis*[2] including *M. winteri* of Java and its allies, or to the peculiar form *M. impura*,[3] Lea, from the Philippines. These have the outer margin of the aperture sinuate and the whorls more or less angulate, but the general form is different, and none have the peculiarly shaped whorls of *M. gradata*.

It is not quite certain, indeed, that the present species was really a *Melania*. The spire resembles that of the curious fresh-water form discovered by Dr. J. Anderson in Yunan, and named *Margarya melanoides* by Mr. G. Nevill (J.A.S.B., Vol. XLVI, 1877, Pt. 2, p. 30, and Vol. L, 1881, p. 155, Pl. V, fig. 1.—Anderson, An. Zool. Res. Western Yunan, p. 891, Pl. LXXX, fig. 5.), but that has the mouth of a *Paludina* and probably, as suggested by Mr. Nevill, is closely allied to that genus, if it does not belong to it.

The typical form of *M. gradata* is represented on Plate 1, figure 3, the large variety in fig. 4, and in fig. 5 the lines of growth are shown.

3. Paludina bugtica, sp. nov., Pl. 1, figs. 6, 7.

Testa imperforata, ovato-conoidea, solida, glabra. Spira conoidea, lateribus convexis, apice obtuso, sutura impressa. Anfr. 4 parum convexi, subplanulati; ultimus haud descendens, subtus rotundatus. Apertura ovato-rotunda, obliqua; peristomate haud incrassato, recto. Long. 0·6; diam. 0·4; ap. long. 0·27 poll. angl.

Shell imperforate, ovately conoid, solid, smooth. Spire conoid with the side convex, apex blunt, suture impressed. Whorls about 4 in number, slightly convex or flattened, generally the latter; the last whorl not descending, rounded below. Aperture nearly round, oblique; peristome not thickened, all in one plane.

[1] Brot, *l. c.*, p. 268.
Ibid, p. 288.

[2] Brot., *l. c.*, p. 289.
Ibid, p. 312.

I am disposed to believe that this species is more probably a *Paludina* than a *Bythinia*, because, had it belonged to the latter genus, I think, in a deposit in which most of the specimens of *Unio* occur with the valves united, that some specimens of the univalve would be found with the shelly opercula in place, just as they commonly are in Indian rivers at the present time.

There is no very closely allied form inhabiting India at the present time (the nearest is perhaps *P. crassa*, Hutton), but *Paludinæ* are not characteristic shells, and a dozen similar species, recent and fossil, might easily be selected for comparison. Two specimens, differing slightly, are represented in figures 6 and 7 of Plate I.

4. UNIO VICARYI, sp. nov. Pl. 2, figs. 1—3.

Testa transversim subtriangulari-ovata, ventricosa, inæquilateralis, concentrice striata, extus atque intus radiatim costata, solida, antice rotundata, postice subangulata; margine dorsali postice primum recto, tunc convexo-declivi, ventrali convexo, postice undulato; umbonibus prominentibus, inflatis; valvulis extus antice glabris, medio ac postice liris sulcisque ornatis, omnibus nisi juxta extremitatem posteriorem subparallelis atque oblique (sc. postice) declinatis, ab margine umbonali ad ventralem decurrentibus, anterioribus minoribus, subdistantibus, mediis 3-4 confertioribus, post medium 3-4 multo majoribus latioribusque, postremis nonnullis brevibus in regione posticâ dorsali, a cæteris divergentibus, atque in marginem posteriorem desinentibus; dentibus cardinalibus magnis. Long. exempli majoris 4; lat. ad 2·25; crass. 2·15 poll. angl.

Shell transversely and subtriangularly ovate, ventricose, especially in the middle, thick, inequilateral, concentrically striated and radiately ribbed both inside and outside, short and rounded anteriorly, subangulate at the posterior end. The dorsal margin is straight for some distance behind the beaks, then rather convex; ventral margin convex, rather prominent in the middle in some specimens, undulating posteriorly opposite the terminations of the ribs on the valves. Umbones prominent and swollen. The valves are nearly smooth near the anterior extremity, but all the rest of the surface is covered with straight ribs and furrows; all the ribs except at the posterior end being subparallel, and sloping obliquely and backwards towards the ventral margin. The first (anterior) ribs are small and subdistant, the next three or four, in the middle of the shell, still small but close together, then a few on the posterior portion of the surface, about 4 in number, are much larger and broader, whilst the dorsal portion of the posterior surface is occupied by a few broad short ribs diverging from the others and running directly towards the posterior end. Cardinal teeth large.

This description is chiefly taken from the only specimen in which the external surface is preserved. The measurements of this specimen are given above. The other examples collected are chiefly casts with the inner portion of the shell remaining. The broad ribs on the posterior surfaces of the valves are preserved in all the casts, and appear as well marked internally as externally, but the finer anterior ribs have disappeared inside the shell. A perfect cast of a shell rather smaller than that of which the dimensions were given above measures—length 3·6, breadth 2·2, thickness 1·9 inches.

I am unacquainted with any species of *Unio*, living or fossil, with which this well marked form can be considered as allied.[1]

Only six specimens of this species were collected; in all but one both valves are in position. Many were seen, but the majority were mere casts or too imperfect to be worth bringing away. The species did not appear to be rare. It is named after Captain Vicary, the original discoverer of the deposit containing the curious series of fresh-water shells now described.

In Plate 2, fig. 1, the specimen above mentioned, in which the surface of the shell is fairly preserved, is represented. Figures 2 and 3 are taken from a well-preserved cast with a little of the shell remaining attached.

5. UNIO CARDIIFORMIS, sp. nov., Pl. 3, figs. 1—6.

Testa fere orbiculata, rotundato-ovalis, subæquilateralis, valde radiatim costata, crassa, ventricosa, antice atque postice rotundata; margine dorsali ante umbones concavo, post eos primum subrecto, deinde convexo; ventrali rotundato, valde undulatim corrugato; umbonibus prominentibus, inflatis; valvulis liris sulcisque radiantibus rectis fere æqualibus, postice declinatis, obtectis; dentibus cardinalibus magnis. Long. 3; lat. 2·6; crass. ad 2 poll. angl.

Shell almost circular, much resembling a *Cardium* or *Pectunculus* in general form and sculpture, subequilateral and ornamented with strong radiating ribs, thick, ventricose, the anterior and posterior ends rounded; the dorsal margin concave in front of the umbones, straight for a short distance behind them, then convex, ventral margin evenly rounded, and deeply corrugated, the corrugations corresponding to the termination of the ribs on the valves. These ribs are straight, nearly equal in size and equidistant; all have a considerable inclination backwards as they pass from the dorsal to the ventral margin. The number appears to vary. In the best preserved example (that figured) there are 14, on another only 11 or 12, the posterior extremity of the shell being in this case smooth, though it is ribbed on the other. Cardinal teeth very large.

The measurements of a large specimen are given above. A smaller and less perfect pair measures—length 2·4, breadth 2·2, thickness 1·6 inches. A cast is 2·5×2·25×1·5.

This and the next species are two of the most remarkable forms of *Unio* ever discovered, and they would probably be made a separate genus by many palæontologists and by some malacologists. There is a slight resemblance between them and certain living American forms, such as *U. plicatus*, Say, and *U. laticostatus*, Lea, but no near connexion. The prominent sculpture formed by the alternating ridges and furrows and the remarkable corrugated ventral margin are exaggerations of the features found in the genus *Cardium*, and rather resemble the peculiar characters of some mesozoic species of *Ostrea*. Some approach to this character is, however, seen in certain intertrappean forms of *Unio* of upper cretaceous age, occurring near Nagpúr.

[1] At first sight it appeared to me that there was a resemblance between both this form and *U. cardiiformis*, and some of the species of *Unio* obtained from the intertrappean (upper cretaceous) beds of Nagpúr and other places in Central India. The same idea occurred independently to Dr. Feistmantel. I was unable to compare the specimens now described with the collection of intertrappean fossils in Calcutta, but although there is a slight similarity between *U. vicaryi* and the intertrappean *U. hunteri*, Hisl. the two do not seem very closely connected.

The cast is almost smooth, the external ribs not being repeated on the inside of the shell except close to the ventral margin.

U. cardiiformis was common at both the places (near Gandoi and near Kumbi) in the Bugti hills, where I found the bed with fresh-water shells, and it was doubtless the species seen by Vicary [1] and taken by him for a *Cardium*. I found either the same or a closely allied form, but poorly preserved, in a bed at nearly the same horizon, close to the base of the Siwalik system, in the Suleimán hills, on the Siri stream, west of Sakhi Sarwar and again in the Vadúr Pass further north. It is possible that the same form was noticed by Mr. Wynne [2] at precisely the same geological horizon in the Kohát district of the Punjab.

As with the other species of *Unio*, the two valves generally occurred together.

Three views of this shell are given on Plate 3, figures 1, 2, 3. Figures 2 and 3 are to some extent restorations, and are intended to show the dorsal and ventral aspects.

5a. UNIO CARDIIFORMIS *var.* (*vel species distincta*). Pl. 3, fig. 4.

Testa trigono-globosa, crassa, ventricosa, costis validis paucis radiatim ornata, antice rotundata, postice subangulata; margine dorsali post umbones declivi, recto; ventrali rotundato, valde undulato, cæterum similis U. cardiiformi typo. Long. 2·2; lat. 2·15; crass. 1·9 poll. angl.

This is probably only a variety of *U. cardiiformis*, with fewer ribs and a more triangular shape. It would doubtless be classed as distinct by many palæontologists and conchologists, but recent forms of *Unio* are excessively variable, and I should not like to propose a name for the present form without more evidence of its distinctness. Only one specimen (a pair of valves as usual) has been brought away. The anterior portion of the shell has perished, and of this part only the cast remains; in the perfect shell there were probably about 8 or 9 radiating ribs on the surface of each valve.

The shell described is represented in figure 4 of Plate 3.

6. UNIO CARDITA. sp. nov., Pl. 1, figs. 8, 9.

Testa ovata, inæquilateralis, mediocriter ventricosa, crassa, costis validis subconfertis, ab margine dorsali ad ventralem subradiatim decurrentibus oblique atque postice declinatis ornata, antice atque postice rotundata; margine dorsali ante umbones concaviusculo, post eos subrecto; ventrali convexo, valde undulato; umbonibus prominentibus; dentibus cardinalibus magnis. Long. 2·75; lat. 2·1; crass. 1·6 poll. angl.

Shell ovate, resembling a *Cardita* in form and sculpture, inequilateral, moderately ventricose, thick; the surface of the valves covered with strong straight radiating ribs not very close together, running obliquely from the dorsal to the ventral margin and inclined posteriorly in the latter direction. Anterior, posterior, and ventral margins rounded, dorsal margin a little concave in front of the umbones, nearly straight and sloping behind, cardinal teeth large.

The measurements of a large specimen are given above; a small pair measures—length 1·85, breadth 1·45, thickness 1·15.

[1] Q. J. G. S., Vol. II, 1846, p. 264. [2] Mem. G. S. I., Vol. XI, pp 61 (165) and 84 (168).

Although this shell, the specific name of which is given on account of its resemblance to the genus *Cardita*, is well distinguished from *U. cardiiformis* both by form and sculpture, the shape being much more ovate and less ventricose, and the ribbing considerably more distant and more oblique, I am far from certain that the two are not varieties of a single form. Only three specimens, a large and a small pair of shells and one cast, belong to *U. cardita*, and the peculiar variety of *U. cardiiformis* last described shows a tendency to a passage, through having fewer ribs than the type. But so well marked a form as *U. cardita* requires nominal distinction at all events, whether connected with *U. cardiiformis* by intermediate links in the same locality or not.

Like its ally, the present species has not, so far as I am aware, any known ally living or fossil.

Two representations of the specimen described are given in figures 8 and 9 of Plate 1.

7. UNIO PUGIUNCULUS, sp. nov., Pl. 1, figs. 10—13.

Testa transversim elongata, pyriformi-ovata, valde inæquilateralis, ventricosa, crassa, antice breviter rotundata, subtruncata, postice attenuata, demum truncatula; margine dorsali postice declivi, fere recto, ventrali convexo, juxta extremitatem posticam concaviusculo, umbonibus prominentibus, inflatis, prope marginem anticum positis, valvula utraque costis duabus, inferiore multo validiore, haud procul a margine dorsali ab umbone ad extremitatem posticam decurrentibus, ornata; dentibus cardinalibus validis. Long. 1·3; lat. 0·8; crass. 0·65 poll angl.

Shell transversely elongate, pyriformly ovate, very inequilateral, ventricose, thick, short and rounded, almost truncate anteriorly, subconical behind, and gradually diminishing to the end, which is cut off, the dorsal margin sloping, almost in a straight line, from the umbones to the posterior extremity, the ventral margin convex throughout the greater part of its length, but slightly concave close to the posterior termination. Umbones prominent, swollen, situated close to the anterior end of the shell, each valve furnished with two ribs near the dorsal margin running from the umbones to the posterior extremity, the inner of the two (that farthest from the dorsal margin) being much the more prominent, and forming, in fact, a division between the general surface of the valve and the hinge area. Cardinal teeth very large and thick.

There is no very near ally of this form living in the peninsula of India, the nearest being species like *U. cæruleus*, Lea, and *U. gerbidoni*, Eydoux. In this case, as in that of *Melania pseudepiscopalis*, much greater similarity can be traced to types existing at present only east of the Bay of Bengal. The closest ally appears to be a form described from Pegu by Mr. Benson under the name of *U. pugio*,[1] and this, again, is said to resemble the Siamese *U. ingallsianus*,[2] Lea. In China, the type is well developed, the extreme form, and one of the best known, and being *U. grayanus*, and some species probably belonging to the same group are found in North America, *e.g.*, *U. nasutus*, Say.[3]

[1] Ann. Mag. Nat. Hist., 3, Vol. X (1862), p. 198, Hanley and Theob. Conch. Ind. Pl. X, fig. 7.
[2] Lea, Trans. Am. Phil. Soc., Vol. X, p. 283, Pl. XXIV, fig. 41. Ev. Conch. Icon., Unio No. 128.
[3] The species named are figured in Lea's Observations; in Küster's Monograph of the genus (Martini and Chemnitz, Syst. Conch. Cab.); and in Reeve's Monograph in the Conchologia Iconica.

[redacted] occurred commonly with the other [redacted] obtained in this condition. Both valves, in this [redacted] were almost always found together, showing that the [redacted] or nearly on the spots where they have been preserved.

[redacted] views of different specimens from different directions are given [redacted] 10, 11, 12. Figure 13 represents a large cast.

[redacted] up. Of the seven species above described four have no [redacted] allies; one more is not nearly represented by any Indian species, but may [redacted] related to forms existing elsewhere; it belongs, however, to a genus in which [redacted] no great variety and which is not very characteristic. Of the remaining [redacted] one, *Melania pseudopiscopalis*, is so closely allied to forms now inhabiting [redacted] and North-Eastern India as to be scarcely separable, and it may be consi[redacted] virtually a living species, whilst the last, *Unio pugiunculus*, although clearly [redacted] from any known living form, is related to a Burmese species, and more distinctly to other forms now inhabiting China and Siam.

Thus of seven fresh-water shells that inhabited the rivers of the north-western Indian frontier in Lower Siwalik times, none are now represented in the surrounding country, five have completely died out, and two have either migrated eastward or [redacted] to the east and disappeared to the west of India.

It is interesting to note that none of the species described appears allied to the [redacted] or Pliocene fresh-water Molluscs of Europe.

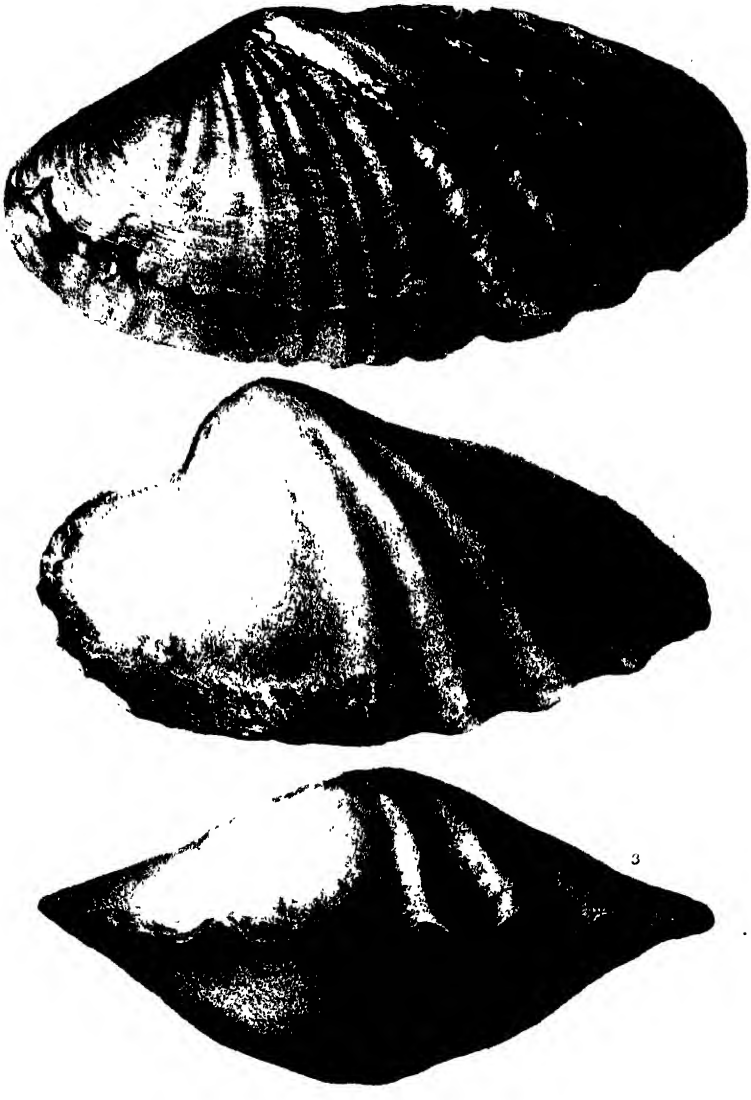
[redacted]

G.M. Herschell ad. nat. lith.

Hannart lith. imp.

LOWER SIWALIK MOLLUSCA

1 2 Melania pseudepiscopalis 3-5 M. gradata.
6 7 Paludina vugtica 8-9 Unio cardita



LOWER SIWALIK MOLLUSCA

13 Unio vicary.

UPPER SIWALIK MOLLUSCA

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